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Erach Bharucha

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ज्ञान-विज्ञानं विमुक्तये

UNIVERSITY GRANTS COMMISSION

TEXTBOOK OF ENVIRONMENTAL STUDIES FOR UNDERGRADUATE COURSES

SECOND EDITION

Textbook of

Environmental Studies

for Undergraduate Courses

Second Edition

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Mahesh Rangrajan.!— Environmental movements in India

Ramchandra Guha !— Use and Abuse of Natu

Core Module Syllabus for Environmental Studies for Undergraduate Courses of all Branches of Higher Education

Unit 1: The Multidisciplinary Nature of Environmental Studies

- Definition, scope and importance
- Need for public awareness

(2 lectures)

Unit 2: Natural Resources

- Renewable and non-renewable resources
- Natural resources and associated problems
  - a) Forest resources: Use and over-exploitation, deforestation, case studies. Timber extraction, mining, dams and their effects on forests and tribal people.
  - b) Water resources: Use and over-utilisation of surface and ground water, floods, drought, conflicts over water, dams-benefits and problems.
  - c) Mineral resources: Use and exploitation, environmental effects of extracting and using mineral resources, case studies.
  - d) Food resources: World food problems, changes caused by agriculture and overgrazing, effects of modern agriculture, fertiliser-pesticide problems, water lagging, salinity, case studies.
  - e) Energy resources: Growing energy needs, renewable and non renewable energy sources, use of alternate energy sources, case studies.
  - f) Land resources: Land as a resource, land degradation, man induced landslides, soil erosion and desertification
- Role of an individual in conservation of natural resources
- Equitable use of resources for sustainable lifestyles

(8 lectures)

Unit 3: Ecosystems

- Concept of an ecosystem
- Structure and function of an ecosystem
- Producers, consumers and decomposers
- Energy flow in the ecosystem

- Ecological succession
- Food chains, food webs and ecological pyramids
- Introduction, types, characteristic features, structure and function of the following ecosystems:
  - a) Forest ecosystems
  - b) Grassland ecosystems
  - c) Desert ecosystems
  - d) Aquatic ecosystems (ponds, streams, lakes, riven, oceans, estuaries)

(6 lectures)

Unit 4: Biodiversity and Its Conservation

- Introduction: Definition: genetic, species and ecosystem diversity
- Biogeographical classification of India
- Value of biodiversity: consumptive use, productive use, social, ethical, aesthetic and option values
- Biodiversity at global, national and local levels
- India as a mega-diversity nation
- Hotspots of biodiversity
- Threats to biodiversity: habitat loss, poaching of wildlife, man-wildlife conflicts
- Endangered and endemic species of India
- Conservation of biodiversity: In situ and Ex situ conservation of biodiversity

(8 lectures)

Unit 5: Environmental Pollution

- Definition
- Causes, effects and control measures of:
  - a) Air pollution
  - b) Water pollution
  - c) Soil pollution
  - d) Marine pollution
  - e) Noise pollution
  - f) Thermal pollution
  - g) Nuclear hazards
- Solid waste management: Causes, effects and control measures of urban and industrial wastes
- Role of an individual in prevention of pollution
- Pollution case studies
- Disaster management: floods, earthquakes, cyclones and landslides

(8 lectures)

Unit 6: Social Issues and the Environment

- From unsustainable to sustainable development
- Urban problems related to energy
- Water conservation, rain water harvesting, watershed management

- Resettlement and rehabilitation of people; its problems and concerns. Case studies.
- Environmental ethics: Issues and possible solutions
- Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust. Case studies.
- Wasteland reclamation
- Consumerism and waste products
- Environment Protection Act
- Air (Prevention and Control of Pollution) Act
- Water (Prevention and Control of Pollution) Act
- Wildlife Protection Act
- Forest Conservation Act
- Issues involved in enforcement of environmental legislation
- Public awareness

(7 lectures)

Unit 7: Human Population and the Environment

- Population growth, variation among nations
- Population explosion—Family Welfare Programme
- Environment and human health
- Human Rights
- Value Education
- HIV/AIDS
- Women and Child Welfare
- Role of Information Technology in Environment and human health
- Case Studies

(6 lectures)

Unit 8: Field Work

- Visit to a local area to document environmental assets—river/forest/grassland/hill/mountain
- Visit to a local polluted site—urban/rural/industrial/agricultural
- Study of common plants, insects, birds
- Study of simple ecosystems-pond, river, hill slopes, etc.

(Fieldwork equal to 5 lecture hours)

Teaching Methodologies

The Core Module Syllabus for Environmental Studies includes classroom teaching and fieldwork. The syllabus is divided into 8 units, covering 50 lectures. The first 7 units, which cover 45 lectures, are classroom-teaching based and intended to enhance knowledge skills and attitude to environment. Unit 8 is based on field activities, to be covered over five lecture hours, and would provide students with first-hand knowledge on various local environmental aspects. Field experience is one of the most effective learning tools for environmental concerns. This moves education out of the scope of the textbook mode of teaching and into the realm of hands-on learning in the field, where the teacher acts as a catalyst to interpret what the student observes or discovers in his/her own environment. Field studies are as essential as class work and form a unique synergistic tool in the entire learning process.

The course material provided by UGC for classroom teaching and field activities should be effectively utilised.

The Universities/colleges can draw upon the expertise of outside resource persons for teaching purposes.

The Environmental Core Module will be integrated into the teaching programs of all undergraduate courses.

Annual system: The duration of the course will be 50 lectures. The exam will be conducted along with the Annual Examination.

Semester system: The Environment Course of 50 lectures will be conducted in the second semester and the examinations shall be conducted at the end of the second semester.

Credit system: The core course will be awarded 4 credits.

Exam pattern: In case of awarding marks, the question paper should carry 100 marks. The structure of the question paper being:

Part A: Short-answer pattern—25 marks
Part B: Essay-type built-in choice—50 marks
Part C: Field work—25 marks

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Unit 1

The Multidisciplinary Nature of Environmental Studies

Let's understand

- The definition of environmental studies, its scope and importance in the educational system
- Why people have to be aware of the environment
- What the institutions that deal with the environment are
- Who the people involved in conservation are

1.1 DEFINITION, SCOPE AND IMPORTANCE

1.1.1 Definition

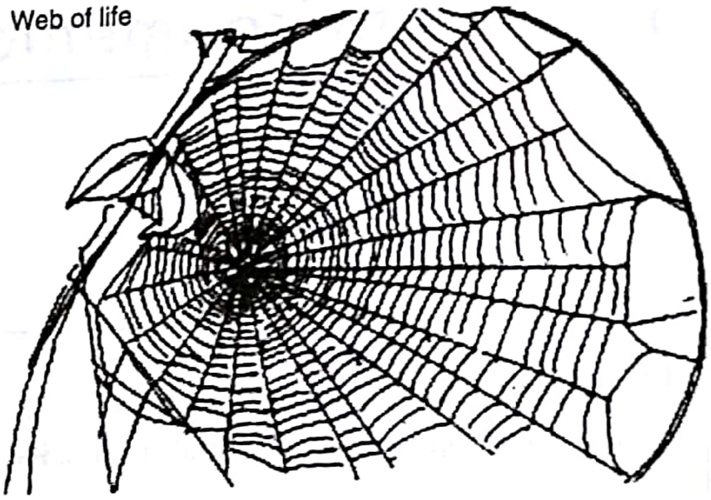
Environmental studies deals with every issue that affects a living organism. It is essentially a multidisciplinary approach that brings about an appreciation of our natural world and human impact on its integrity. It is an applied science, as it seeks practical answers to the increasingly important question of how to make human civilisation sustainable on the finite resources that are available.

Its components include biology, geology, chemistry, physics, engineering, sociology, health, anthropology, economics, statistics, computers and philosophy.

1.1.2 Scope

Environment is not a single subject; it is an integration of several subjects that include both science and social studies. To understand all the different aspects of our environment, we need to understand biology, chemistry, physics, geography, resource management, economics and population issues. Thus, the scope of environmental studies is extremely wide and covers some aspects of nearly every major discipline.

If we study the natural history of the areas in which we live, we would see that our surroundings were originally a natural landscape, such as a forest, a river, a mountain, a desert, or a combination of these elements. Most of us live in landscapes that have been profoundly modified by human beings—in villages, towns or cities. But even those of us who live in cities must get our food supply from the surrounding villages and these, in turn, are dependent on natural landscapes such as forests, grasslands, rivers, seashores, for resources such as water for agriculture, fuelwood, fodder and fish. Thus, our daily lives are inextricably linked to our surroundings and inevitably affect them.



We use water to drink and for other day-to-day activities. We breathe air, we use resources from which food is made, and we depend on the community of living plants and animals which form a web of life, of which we are also a part. Everything around us forms our environment and our lives depend on keeping its vital systems as intact as possible.

Our dependence on nature is so great that we cannot continue to live without protecting the earth's environmental resources. Thus, most traditions refer to our environment as *Mother Nature* and most traditional societies have learned that respecting nature is vital for protecting their own livelihoods. This has led to many cultural practices that have helped traditional societies protect and preserve their natural resources. Respect for nature and all living creatures is not new to India; all our traditions are based on these values. Emperor Ashoka's edict proclaimed that all forms of life are important for our well-being, back in the 4th century BCE.

Over the past 200 years, however, modern societies began to believe that easy answers to the question of producing more resources could be provided by the indiscriminate application of technological innovations. Some examples are: growing more food by using fertilisers and pesticides, developing better strains of domestic animals and crops, irrigating farmland through mega-dams and developing industry. All this has led to rapid economic growth; and this type of ill-considered development has inevitably led to environmental degradation, besides several harmful effects as well.

Industrial development and intensive agriculture that provides the goods for our increasingly consumer-oriented society also uses up large amounts of natural resources like water, minerals, petroleum products, wood and so on. Non-renewable resources, such as minerals and oil, will be exhausted in the near future if we continue to extract these without a thought for subsequent generations. Renewable resources, such as timber and water, can be used but be regenerated by natural processes such as regrowth and rainfall. However, these too will be depleted if we continue to use them faster than nature can replace them. For example, if the removal of timber and firewood from a forest is faster than the regrowth and regeneration of trees, the supply of wood cannot be replenished. And the loss of forest cover not only depletes the forest of its resources, such as timber and other non-wood products, but also affects our water resources because an intact natural forest acts like a sponge which holds water in the rainy season and releases it slowly over the drier periods. In addition, deforestation leads to floods in the monsoon season and dry rivers once the rains are over.

Such multiple effects on the environment resulting from routine human activities must be understood by each one of us, if it is to provide us with the resources we need in the long term.

Our natural resources can be compared with money in a bank. If we use it rapidly, the capital will be reduced to zero. On the other hand, if we use only the interest, it can sustain us over the longer term. This is called sustainable development. Thus each professional in their field should strive to achieve sustainable development through their actions.

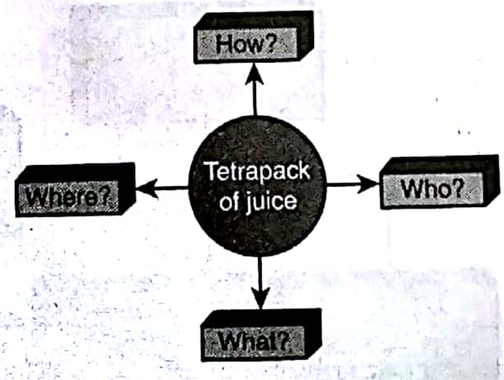
Let's do it!

- Take any article that you use in daily life—a bucket full of water, an item of food, a table or a book.
- Trace its components through a journey backwards from your home to its origins as natural resources in our environment.
- Are you using that resource unsustainably?
- In what ways could you reduce, reuse and recycle that resource?
- Is there an unequal distribution of this resource, so that you are more fortunate than many others who have less access to it?
- What can you do to prevent waste and reuse articles that you normally throw away? What recycled materials can you use?
- Think of the various energy sources you use every day. How could you reduce their use?

Understanding and making ourselves more aware of our environmental assets and problems is not enough. Each one of us must become more concerned about our environment and

For every resource we use, we must ask ourselves the following questions:

- What is the value of the resource and where does it originate?
- Who uses it most intensively and how?
- How is it being overused or misused?
- Who is responsible for its improper use—the resource collector, the middle-man, the end-user?
- How can we help conserve it and prevent its unsustainable use?



change the way in which we use every resource. Most of us indulge in wasteful behaviour patterns without ever thinking about their environmental impact. Thus, for all our actions to be environmentally friendly, we need to analyse them from the new perspective of how we use resources.

Once we begin to ask these questions of ourselves, we will begin to live lifestyles that are more sustainable and will support our environment.

1.1.3 Importance

We live in a world where natural resources are limited. Water, air, soil, minerals, oil, the products we get from forests, grasslands, oceans and from agriculture and livestock, are all a part of our life-support systems. Without them, life itself would be impossible. As we keep increasing in number and the quantity of resources each of us uses also increases, the earth's resource base must inevitably shrink. The earth cannot be expected to indefinitely sustain this expanding level of utilisation of resources. Added to this is the risk of misuse of resources. Increased amounts of waste and pollution contaminating our existing supply is a threat to the quality of life for all. This situation will only improve if each of us begins to take actions in our daily lives that will help preserve our environmental resources.

Figure 1.1 illustrates the Total Economic Value—direct and indirect use value of a given ecosystem. This is a tool commonly used in environmental economics to determine the function-based values provided by an ecosystem. Figure 1.2 illustrates the importance of preserving ecosystems by listing the services they provide at global, regional and local scales.

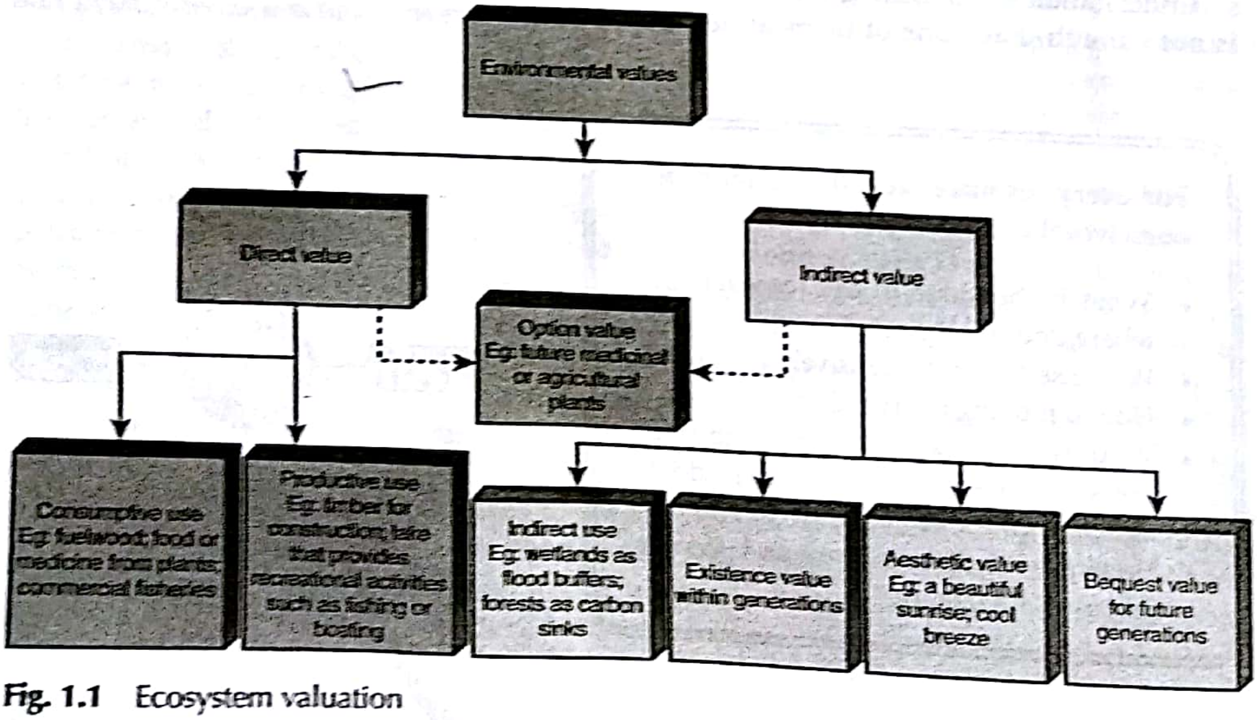

Environmental values
Direct value
Indirect value
Option value Eg: future medicinal or agricultural plants
Consumptive use Eg: fuelwood, food or medicine from plants; commercial fisheries
Productive use Eg: timber for construction; lake that provides recreational activities such as fishing or boating
Indirect use Eg: wetlands as flood buffers; forests as carbon sinks
Existence value within generations
Aesthetic value Eg: a beautiful sunrise; cool breeze
Bequest value for future generations

Fig. 1.1 Ecosystem valuation

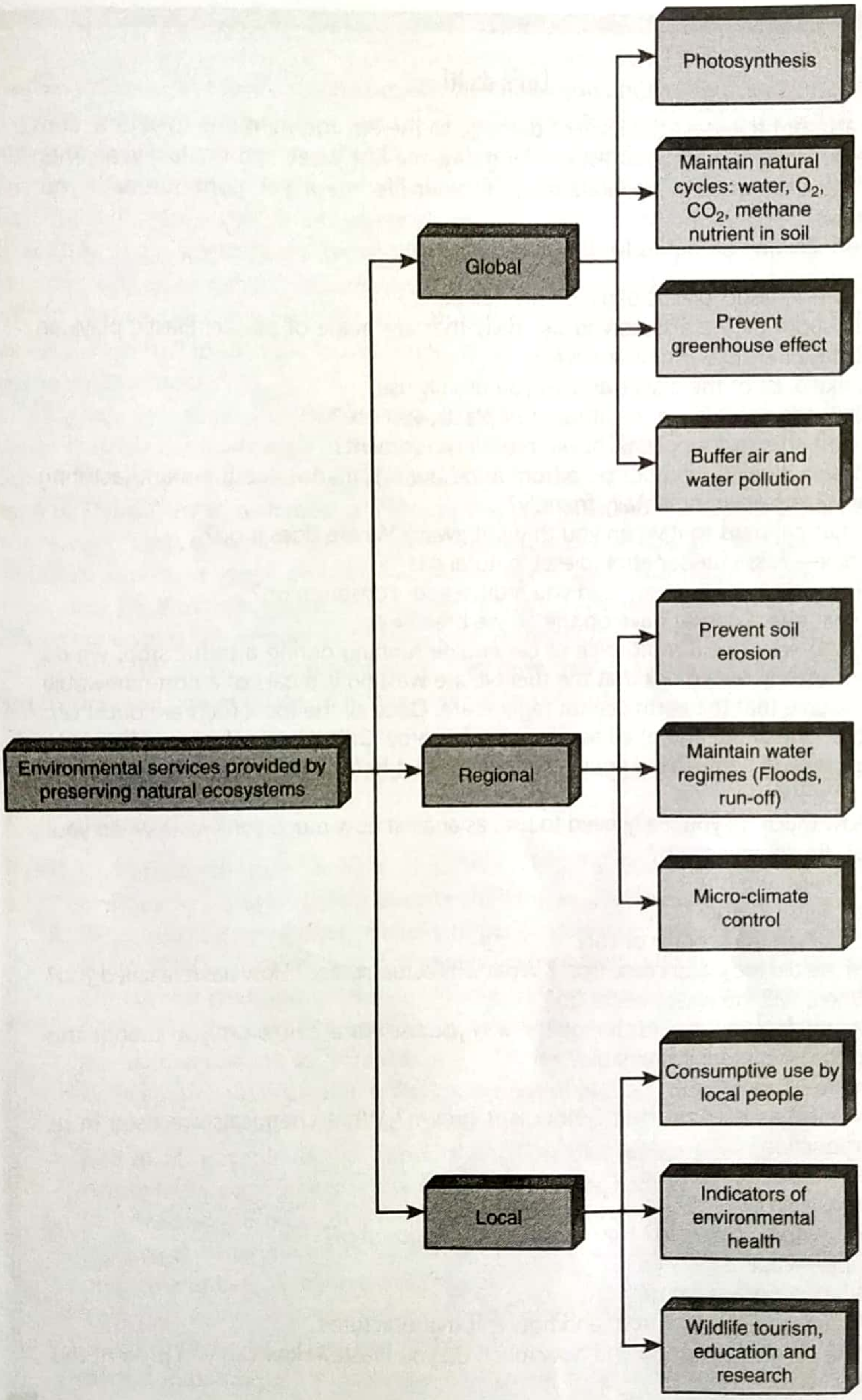

Environmental services provided by preserving natural ecosystems
Global
Regional
Local
Photosynthesis
Maintain natural cycles: water, O2, CO2, methane nutrient in soil
Prevent greenhouse effect
Buffer air and water pollution
Prevent soil erosion
Maintain water regimes (Floods, run-off)
Micro-climate control
Consumptive use by local people
Indicators of environmental health
Wildlife tourism, education and research

Fig. 1.2 Environmental services provided by ecosystems

Let's do it!

Make an attempt to assess the level of damage to the environment due to your actions that have occurred during your last working day, the last week and the last year. Then estimate the damage you are likely to do in your lifetime if you continue with your present ways.

Use the following examples for the above exercise:

(i) Example—Plastic: plastic bags, plastic ball pens
Think about all the articles you use daily that are made of plastic. Plastic plays an important part in our modern lives.
- Make a list of the plastic articles you usually use.
- How can you reduce the amount of plastic you use?
- What effects does plastic have on our environment?
- Where does the plastic come from and how is it made? Are the manufacturing processes environmentally friendly?
- What happens to it when you throw it away? Where does it go?

(ii) Example—Fossil fuels: petrol, diesel, natural gas
- How much do you use? Can you reduce your consumption?
- What effect does it have on the air we breathe?
- When we leave a motorbike or car engine running during a traffic stop, we do not usually remember that the fuel we are wasting is a part of a non-renewable resource that the earth cannot regenerate. Once all the fossil fuels are burnt off, it will mean the end of oil as a source of energy. Only if each of us contributes to conserving fossil-based energy can we make it last longer.

(iii) Example—Water
- How much do you really need to use, as against how much you waste when you:
  (a) Brush your teeth?
  (b) Have a bath?
  (c) Wash clothes?
  (d) Wash the scooter or car?
- Where did the water come from? What is its actual source? How has it reached you?
- Where will the waste water go?
- Do you feel you should change the way you use water? How can you change this so that it is more sustainable?

(iv) Example—Food
- Where has it come from? How is it grown? What chemicals are used in its production?
- How does it reach you?
- How is it cooked?
- How much is wasted? How is the waste disposed of?

(v) Example—Paper
- What is it made from?
- Where does it come from and how is it manufactured?
- How much do you use and how much do you waste? How can you prevent this wastage?

1.2 NEED FOR PUBLIC AWARENESS

As the earth's natural resources are rapidly dwindling and our environment is being increasingly degraded by human activities, it is evident that something needs to be done. We often feel that managing all this is something that the Government should do. But if we continue to endanger our environment, there is no way by which the Government can perform all these clean-up functions. It is the prevention of environmental degradation that must become a part of all our lives. Just as for any disease, prevention is better than cure, protecting our environment is economically more viable than cleaning it up once it is damaged. Individually, we can play a major role in environment management. We can reduce wastage of natural resources and we can act as watchdogs that inform the Government about sources that lead to pollution and degradation of the environment.

This can only be made possible through public awareness. Mass media such as newspapers, radio and television strongly influence public opinion. However, someone has to bring this about. If each of us feels strongly about the environment, the press and media will add to our efforts. Politicians in a democracy always respond positively to a strong publicly-supported movement. Thus, if you join an NGO that supports conservation, you might be able to influence politicians to make green policies. We are living on 'spaceship earth' with a limited supply of resources. Each of us is responsible for spreading this message to as many people as possible. There are several Government and Non-Government Organisations (NGOs) working towards environmental protection in our country. They have created a growing interest in environmental protection and conservation of nature and natural resources.

Let's also do these!

- Join a group to study nature, such as World Wildlife Fund for Nature-India (WWF-I) or Bombay Natural History Society (BNHS), or another environmental group.
- Begin reading newspaper articles and periodicals like *Down to Earth*, *WWF-I Newsletter*, *BNHS*, *Hornbill*, *Sanctuary* magazine or others, which will tell you more about our current environmental issues. There are also several environmental websites.
- Lobby for conserving resources by taking up the cause of environmental issues during discussions with friends and relatives. Practice and promote issues such as saving paper, saving water, reducing the use of plastics, practising the 3Rs principle of 'Reduce, Reuse, Recycle', and proper waste disposal.
- Join local movements that support activities like saving trees in your area, go on nature treks, recycle waste, buy environmentally-friendly products.
- Practice and promote good civic sense and hygiene such as enforcing no spitting or tobacco chewing, no throwing garbage on the road, no smoking in public places, no urinating or defecating in public places.
- Take part in events organised on World Environment Day, Wildlife Week and other environment-significant days (Table 1.1).
- Visit a national park or sanctuary, or spend time in whatever natural habitat you have near your home.

Table 1.1 Environmentally significant days

Day and month	Event
02 February	World wetland day
28 February	National science day
21 March	World forestry day
22 March	World water day
18 April	World heritage day
22 April	Earth day
22 May	International biodiversity day
05 June	World environment day
11 July	World population day
16 September	World ozone day
28 September	Green consumer day
03 October	World habitat day
1–7 October	Wildlife week
04 October	Animal welfare day
02 December	Bhopal tragedy day

1.2.1 Institutions in Environment

Among the large number of institutions that deal with environmental protection and conservation, a few well-known organisations include government organisations like the Ministry of Environment and Forest (MoEF), Environmental Information System (ENVIS), Pollution Control Boards and Zoological Survey of India (ZSI), and NGOs like the BNHS, WWF-I and others.

Bombay Natural History Society (BNHS), Mumbai

The BNHS began as a small society of six members in 1883. It grew from a group of *shikaris* and people from all walks of life into an important research organisation that substantially influences conservation policy in the country. Its influence on wildlife policy building, research, popular publications and peoples' action has been a unique feature of the multifaceted society. Undoubtedly its major contribution has been in the field of wildlife research. It is India's oldest conservation research-based NGO and one that has been at the forefront of the battle for preservation of species and ecosystems. The BNHS publishes a popular magazine called the *Hornbill* and also an internationally well-known *Journal on Natural History*. Its other publications include Salim Ali's *Handbook on Birds*, JC Daniel's *Book of Indian Reptiles*, SH Prater's *Book of Indian Mammals* and PV Bole's *Book of Indian Trees*. One of its greatest scientists was Salim Ali, whose ornithological work on the birds of the Indian subcontinent is world famous. The BNHS has over the years helped the Government to frame wildlife-related laws and has taken up battles such as the 'Save the Silent Valley' campaign.

Botanical Survey of India (BSI)

The BSI was established in 1890 at the Royal Botanic Gardens, Calcutta. However it closed down for several years after 1939. After reorganisation, with the development and establishment of different regional centres, the aims and objectives of the Survey were redefined by the Programme Implementation and Evaluation Committee in 1976 with a view to encourage taxonomic research and to accelerate scientific expertise for the preparation of a comprehensive list of the flora of the country, under the 'Flora of India' project, ethnobotanical study, modernisation and maintenance of herbaria and museums, and creating interests among botanists and the public in general. In a recent review (1987), the aims and objectives of Botanical Survey remained unchanged except that activities like the survey and exploration of plant resources, listing of endangered species, publication of national flora, preparation of national data bank on herbarium and live collection, plant distribution and nomenclature were prioritised.

Bharati Vidyapeeth Institute of Environment Education and Research (BVIEER), Pune

This is part of the Bharati Vidyapeeth Deemed University. The Institute has a PhD and a Masters program in Environmental Sciences and Geoinformatics. It also offers an innovative Diploma in Environment Education for in-service candidates. It implements a large outreach program that has covered over 435 schools which involves training teachers and conducting Environment Education Programmes. Research at the institute focuses on biodiversity conservation, urban planning, clean technology, environment education and wildlife management. It develops low-cost Interpretation Centres for natural and architectural sites that are highly locale-specific as well as a large amount of innovative environment educational material for a variety of target groups.

Central Pollution Control Board (CPCB)

It is a statutory organisation which was constituted in 1974 under the Water (Prevention and Control of Pollution) Act, 1974 and under the Air (Prevention and Control of Pollution) Act, 1981 to prevent and control pollution to improve the quality of India's environment. A large number of activities and programmes have been started such as the development of source-specific pollution control norms and guidelines based on available scientific understanding, setting up of ambient air and water quality criteria, monitoring of ambient air and water quality, auto fuel quality and emission norms for controlling vehicular pollution and planning for environmentally sound industrial development. Besides the CPCB, there are 22 State Pollution Control Boards/ Pollution Control Committees which are responsible for regulating and implementing environmental protection and pollution control within the state. These State Pollution Boards are autonomous statutory bodies which are bound to report to the CPCB for any critical matter.

Centre for Science and Environment (CSE), New Delhi

The activities of this centre include organising campaigns, holding workshops and conferences, and producing environment-related publications. It has published a major document on the *State of India's Environment*, the first of its kind to be produced as a Citizen's Report on the Environment. The CSE also publishes a popular magazine, *Down to Earth*, which is a science and environment fortnightly. It is involved in the publication of material in the form of books, posters and video films and also conducts workshops and seminars on biodiversity-related issues.

CPR Environmental Education Centre (CPR-EEC), Chennai

This was set up in 1988. It conducts a variety of programs to spread environmental awareness and create an interest in conservation among the general public. It focusses attention on NGOs, teachers, women, youth and children, to generally promote conservation of nature and natural resources. Its programmes include components on wildlife and biodiversity issues. CPR-EEC also produces a large number of publications.

Centre for Environment Education (CEE), Ahmedabad

This was initiated in 1989. It has a wide range of programmes on the environment and produces a variety of educational material, for various target groups.

Ministry of Environment and Forest (MoEF)

The MoEF is primarily concerned with the planning, promotion and coordination of the implementation of India's environmental and forestry policies and programmes. The primary concern of the Ministry lies in the implementation of policies and programmes relating to the conservation of the country's natural resources including lakes and rivers, its biodiversity, forests and wildlife, ensuring the welfare of its animals and prevention and abatement of pollution. These objectives are well supported by a set of legislative and regulatory measures, aimed at the preservation, conservation and protection of the environment. The Ministry also serves as the nodal agency in the country for the United Nations Environment Programme (UNEP), South Asia Cooperative Environment Programme (SACEP), International Centre of Integrated Mountain Development (ICIMOD) and for the follow-up of the United Nations' Conference on Environment and Development (UNCED). The Ministry is entrusted with issues relating to multilateral bodies such as the Commission on Sustainable Development (CSD), Global Environment Facility (GEF) and of regional bodies like the Economic and Social Council for Asia and Pacific (ESCAP) and South Asian Association for Regional Cooperation (SAARC) on matters relating to the environment.

As a part of the MoEF's planning of environmental policies, the Environmental Information System (ENVIS) was established in 1982 by the Government of India. The focus of ENVIS is to provide environmental information to decision makers, policy planners, scientists, engineers and research workers all over the country. ENVIS is a decentralised system with a network of distributed subject-oriented centres ensuring integration of national efforts in environment information collection, collation, storage, retrieval and dissemination to all concerned. A large number of nodes, known as ENVIS centres, have been established in the network to cover the broad subject areas of environment with a focal point in the MoEF. These centres have been set up on areas such as pollution control, toxic chemicals, central and offshore ecology, environmentally sound and appropriate technology, biodegradation of waste and environment management.

Madras Crocodile Bank Trust (MCBT)

MCBT, the first crocodile conservation breeding centre in Asia, was founded in 1976 to conserve Indian crocodiles and establish a programme for the conservation and propagation of other species of endangered reptiles. Over the years, over 1500 crocodiles and several hundred eggs have been supplied to various State Forest Departments for restocking programmes in the wild and for setting up breeding facilities in other states of India and neighbouring countries. MCBT started the first sea turtle survey and conservation programme in India, including a sea turtle hatchery.

The Crocodile Bank is the site of the Irula Snake Catchers' Cooperative Society, which is an Adivasi self-help project and supplies all of India's snake and scorpion venom needed for the production of anti-venom and for medical use.

State Department of Environment

It is present in every state of India. It is responsible for improving the overall environmental quality within that state. The Department actively engages in environmental assessment, monitoring, protection and awareness amongst people in the state.

Salim Ali Centre for Ornithology and Natural History (SACON), Coimbatore

This institution was Salim Ali's dream, which became a reality only after his demise. Initially conceived as being a wing of the BNHS, it later evolved into an independent organisation based at Coimbatore in 1990. It has instituted a variety of field programmes that have added to the country's information on our threatened biodiversity.

World Wide Fund for Nature-India (WWF-I), New Delhi

The WWF-I was initiated in 1969 in Mumbai, after which the headquarters were shifted to Delhi with several branch offices all over India. The early years focused attention on wildlife education and awareness. It runs several programmes, including the Nature Clubs of India programme for school children and works as a think-tank and lobby force for environmental and developmental issues.

Wildlife Institute of India (WII), Dehradun

This institution was established in 1982, as a major training establishment for Forest Officials and for research in Wildlife Management. Its most significant publication has been *Planning a Wildlife Protected Area Network for India* (Rodgers and Panwar, 1988). The organisation has over the years added an enormous amount of information on India's biological wealth. It has trained a large number of Forest Department officials and staff as Wildlife Managers. Its MSc Program has trained excellent wildlife scientists. It also has an Environment Impact Assessment (EIA) cell. It trains personnel in ecodevelopment, wildlife biology, habitat management and nature interpretation.

Zoological Survey of India (ZSI)

The ZSI was established in 1916. Its mandate was to do a systematic survey of the

Museum at Calcutta, which was established in 1875. The older collections of the Asiatic Society of Bengal, which were made between 1814 and 1875, as well as those of the Indian Museum, made between 1875 and 1916, were then transferred to the ZSI. Today, it has over a million specimens! This makes it one of the largest collections in Asia. It has done an enormous amount of work on taxonomy and ecology. It currently operates from 16 regional centres.

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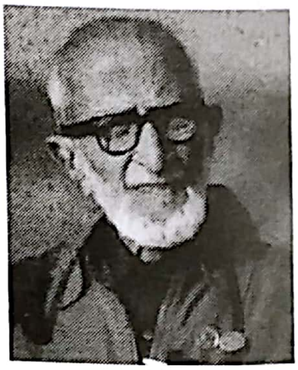
1.2.2 People in Environment

There are several internationally-known environmental thinkers. Among those who have made landmark contributions, the names that are usually mentioned are Charles Darwin, Ralph Emerson, Henry Thoreau, John Muir, Aldo Leopold, Rachel Carson and EO Wilson. Each of these thinkers looked at the environment from a completely different perspective. Charles Darwin wrote the *Origin of Species*, which brought to light the close relationship between habitats and species. It brought about a new way of thinking about our relationship with other species that was based on evolution. Ralph Emerson spoke of the dangers of commerce to our environment way back in the 1840s. Henry Thoreau, in the 1860s, wrote that the wilderness should be preserved after he had lived in it for a year. He felt that most people did not care for nature and would sell it off for a small sum of money. John Muir is remembered as having saved the great ancient sequoia trees in California's forests. In the 1890s, he formed the Sierra Club, which is a major conservation NGO in the USA. Aldo Leopold was a forest official in the US in the 1920s. He designed the early policies on wilderness conservation and wildlife management. In the 1960s, Rachel Carson published several articles that caused immediate worldwide concern on the effects of pesticides on nature and humans. She wrote a well-known book called *Silent Spring*, which eventually led to a change in Government policy and public awareness. EO Wilson is an entomologist who envisioned that biological diversity was the key to human survival on earth. He wrote *Diversity of Life* in 1993, which was awarded a prize for the best book published on environmental issues. His writings brought home to the world the risks to humans from artificial disturbances in natural ecosystems that are leading to the rapid extinction of species at a global level.



A number of individuals have been instrumental in shaping the environmental history in our country. Some of the well-known names in the last century include environmentalists, scientists, administrators, legal experts, educationists and journalists. **Salim Ali's** name is synonymous with ornithology in India and with the BNHS. He also wrote several great books including the famous *Book of Indian Birds*. His autobiography, *Fall of a Sparrow*, should be read by every nature enthusiast. He was our country's leading conservation scientist and influenced environmental policies in our country for over 50 years.

Indira Gandhi as Prime Minister played a very significant role in the preservation of India's wildlife. It was during her period as PM, that the network of Protected Areas (PAs) grew from 65 to 298! The

Wildlife Protection Act was formulated during the period when she was PM and the Indian Board for Wildlife was extremely active as she personally chaired all its meetings. India gained a name for itself by being a major player in the Convention on International Trade in Endangered Species (CITES) and other International Environmental Treaties and Accords during her tenure. BNHS frequently used her goodwill to get conservation action initiated by the Government.

MS Swaminathan is one of India's foremost agricultural scientists and has also been concerned with various aspects of biodiversity conservation, both of cultivars and of wild biodiversity. He founded the MS Swaminathan Research Foundation in Chennai, which does work on the conservation of biological diversity.

Madhav Gadgil is a well-known ecologist in India. His interests range from broad ecological issues such as developing Community Biodiversity Registers and conserving sacred groves to studies on the behaviour of mammals, birds and insects. He has written several articles, published papers in journals, is the author of 6 books, and the editor for the series *Lifescapes of Peninsular India.*

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MC Mehta is undoubtedly India's most famous environmental lawyer. Since 1984, he has filed several Public Interest Litigations supporting the cause of environmental conservation. His most famous and long-drawn battles supported by the Supreme Court include protecting the Taj Mahal, cleaning up the Ganges River, banning intensive shrimp farming on the coast, urging the Government to implement environmental education in schools and colleges, and a variety of other conservation issues.

Anil Agarwal was a journalist who wrote the first report on the *State of India's Environment* in 1982. He founded the Centre for Ecological Sciences (CES), an active NGO that supports various environmental issues.

Medha Patkar, known as one of rural India's champions, has supported the cause of the downtrodden tribal people whose environment is being affected by dams on the Narmada River.

Sunderlal Bahuguna's *Chipko Movement* has become an internationally well-known example of a highly successful conservation action programme through the efforts of local people for guarding their forest resources. His fight to prevent the construction of the Tehri Dam in a fragile earthquake-prone setting is a battle that he continues to wage. The Garhwal Hills will always remember his dedication to the cause for which he has walked over 20 thousand kilometres.

Summary

- Environmental studies involves understanding human interactions with the environment. It requires an integrated approach to several disciplines of science and social studies.
- We live in a world where natural resources such as land, water, forests, minerals, oil, grasslands and wetlands are limited. We cannot continue to over-utilise these resources beyond the earth's assimilative capacity. Thus, the sustainable use of resources is of utmost importance.
- Everything around us forms our environment and our lives depend on keeping its vital systems intact. We need to individually take responsibility towards preserving our environmental resources.

Questions

1. What is the scope of environmental studies?
2. What is the importance of environmental studies?
3. What are some of the activities that you can be a part of to raise environmental awareness amongst people?
4. Name one well-known environmental thinker who inspires you and explain why.
5. Name and describe the activities of any environmental institution that you are aware of.
6. What are the environmental concerns in your area of work? Discuss the means to address the same.

Unit 2

Natural Resources

Let's understand

- What renewable and non-renewable resources are
- About the role of an individual in the conservation of natural resources
- How resources can be used equitably for sustainable lifestyles

2.1 INTRODUCTION

The environment provides us with a variety of goods and services necessary for our day-to-day life. These natural resources include air, water, soil and minerals, along with the climate and solar energy, which form the non-living or 'abiotic' part of nature. The 'biotic' or living parts consist of plants and animals, including microbes. Plants and animals can only survive as communities of different organisms, all closely linked to each other in their own habitat, and requiring specific abiotic conditions. Thus, forests, grasslands, deserts, mountains, rivers, lakes and the marine environment all form habitats for specialised communities of plants and animals to live in. The interactions between the abiotic aspects of nature and specific living organisms together form ecosystems of various types. Many of these living organisms are used as food resources. Others are linked to food less directly, like bees as pollinators and dispersers of plants, soil animals like worms which recycle nutrients for plant growth, and fungi and termites that break up dead plant material so that microorganisms can act on the detritus to replenish soil nutrients.

Resource use over time

About ten thousand years ago, when humans changed from hunter–gatherers, living in wilderness areas such as forests and grasslands, into agriculturalists and pastoralists, we began to change the environment to suit our own requirements. As our ability to grow food and use domestic animals developed, these 'natural' ecosystems were converted into agricultural land. Most પારંપારિક traditional agriculturists depended extensively on natural sources—rain, streams and rivers—for water. Later, they began to use wells to tap underground water sources, impound water and create irrigated land by building dams. Recently, we have begun to use fertilisers and pesticides to further boost the yield from the same amount of land. However, we now realise that all this has led to several undesirable changes in our environment. Humans have been overusing and depleting natural resources. The over-intensive use of land has exhausted the capability of the ecosystem to support the growing demands of more and more people, all requiring more intensive use of resources. Industrial growth, urbanisation, population growth and the enormous increase in the use of consumer goods have further stressed the environment, as they create great quantities of solid waste. Air, water and soil pollution, in turn, have begun to seriously affect human health.

Historical changes in land and resource use

During the last 100 years, a better healthcare delivery system and improved nutrition has led to rapid population growth, especially in the developing countries. This phenomenal rise has placed great demands on the earth's natural resources. Large stretches of land – forests, grasslands and wetlands – have been put to agricultural and industrial use. These changes have brought about dramatic alterations in land use patterns and the rapid disappearance of valuable natural ecosystems. The need for more water, more food, more energy and more consumer goods is not only the result of a greater population, but also that of an increasing consumerist society.

Industrial development is aimed at meeting growing demands for all consumer items. However, these consumer goods also generate waste in ever larger quantities. As shown in Fig. 2.1, the growth of industrial complexes has also led to a shift of people from their traditional, sustainable, rural way of life to urban centres that developed around industries. During the last few decades, several small urban centres have become large cities; some have even become giant mega cities. This has increased the disparity between what the surrounding land can produce and what the large numbers of people in these areas of high population density

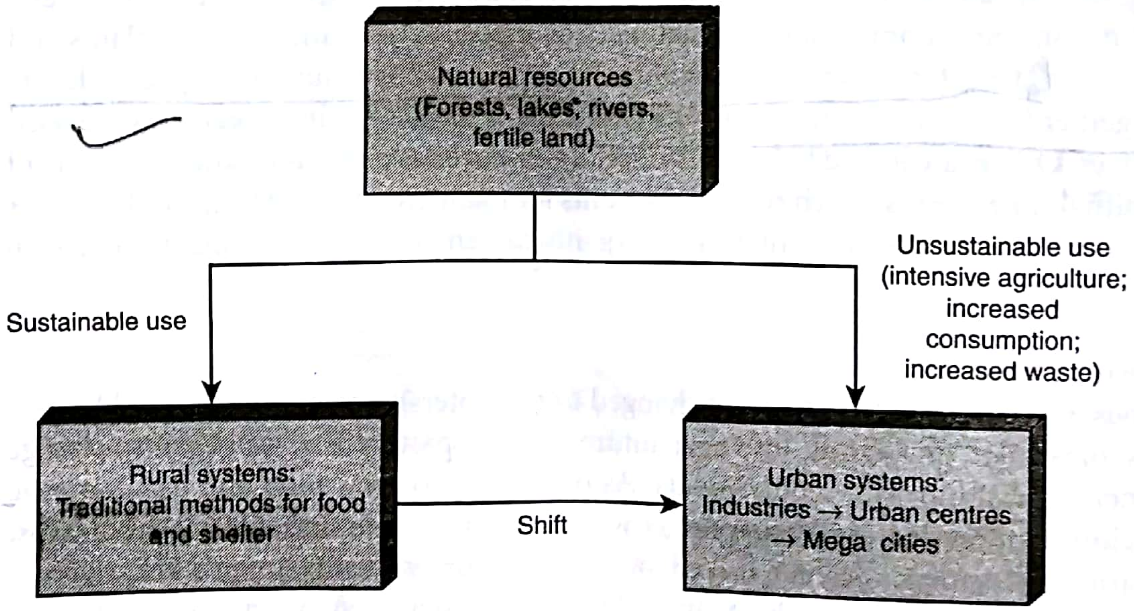

Natural resources (Forests, lakes, rivers, fertile land)
Sustainable use
Unsustainable use (intensive agriculture; increased consumption; increased waste)
Rural systems: Traditional methods for food and shelter
Shift
Urban systems: Industries → Urban centres → Mega cities

Fig. 2.1 Shift in pressure of natural resources from rural to urban systems

consume. Urban centres cannot exist without resources such as water from rivers and lakes, food from agricultural areas, domestic animals from pasture land and timber, fuelwood, construction material and other resources from forests. Rural agricultural systems are dependent on forests, wetlands, grasslands, rivers and lakes. The resulting movement of natural resources from the wilderness ecosystems and agricultural sector to the urban user has led to a serious inequality in the distribution of resources among human beings, which is both unfair and unsustainable.

Earth's Resources and Humans

The resources on which humans depend are provided by various sources or 'spheres', shown in Fig. 2.2.

(i) The atmosphere

- Oxygen for human respiration (metabolic requirements)
- Oxygen for wild fauna in natural ecosystems and domestic animals used by humans as food
- Oxygen as a part of carbon dioxide, used for the growth of plants (which in turn are used by humans)

The atmosphere forms a protective shell over the earth. The lowest layer or troposphere, the only part warm enough for us to survive in, is only 12 km thick. If the earth were the size of an apple, this lower layer of atmosphere that we breathe would be no thicker than the apple's skin! The stratosphere is 50 km thick and contains a layer of sulphates, which is important for the formation of rain. It also contains a layer of ozone, which absorbs ultraviolet (UV) light known to cause cancer, and without which no life could exist on earth. The atmosphere is not uniformly warmed by the sun. This leads to air flows and variations in climate, temperature and rainfall in different parts of the earth. It is a complex dynamic system; if disrupted, it affects everybody. Most air pollutants have both global and regional effects.

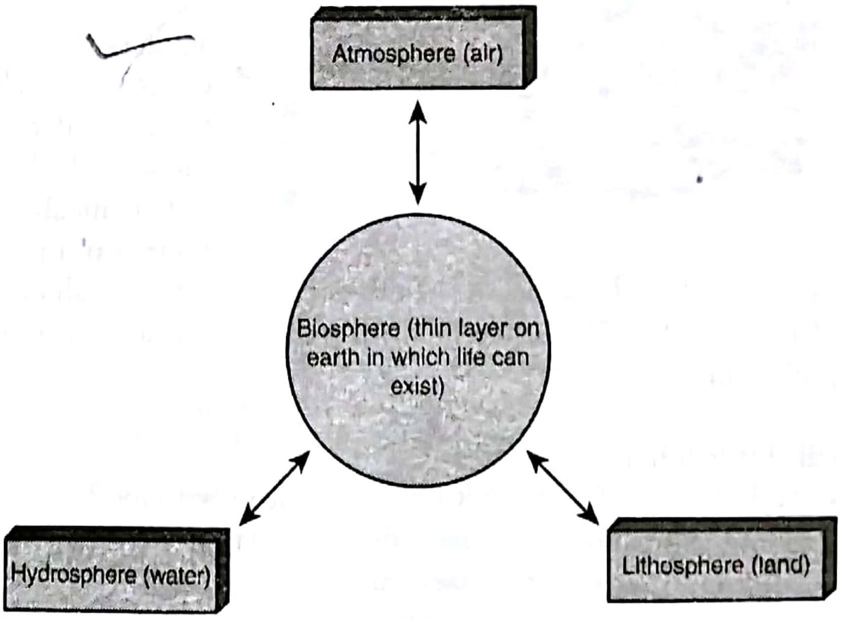


Fig. 2.2 Earth's spheres

Living creatures cannot survive without air even for a few minutes. To continue to support life, the air must be kept clean. Many of the major pollutants of air are created by industrial units that release gases such as carbon dioxide, carbon monoxide and toxic fumes into the air. The air is also polluted by burning fossil fuels. The build-up of carbon dioxide in the atmosphere, known as the 'greenhouse effect', has led to the current global warming. The growing number of scooters, motorcycles, cars, buses and trucks, which all run on fossil fuel (petrol and diesel), is a major cause of air pollution in cities and along highways.

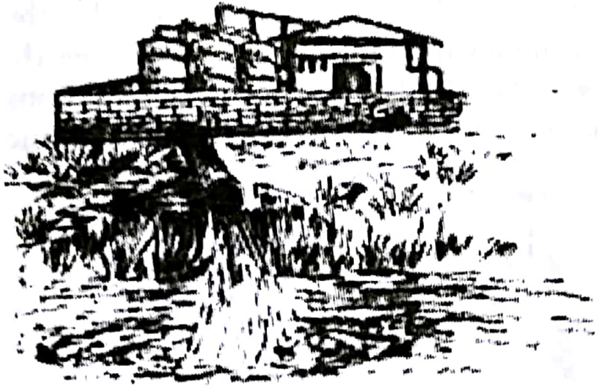
Air pollution severely affects human health; it leads to acute and chronic respiratory diseases such as lung infections, asthma and even cancer.

Burning garbage

(ii) Hydrosphere

- Clean water for drinking (a metabolic requirement for all living processes)
- Water for washing and cooking
- Water used in agriculture and industry
- Food resources from the sea, including fish, crustaceans and seaweed
- Food from freshwater sources, including fish, crustaceans and aquatic plants
- Water flowing down from mountain ranges, harnessed to generate electricity in hydroelectric projects

Water pollution



The hydrosphere covers three-quarters of the earth's surface. A major part of the hydrosphere is the marine ecosystem in the ocean, while only a small part is freshwater. The freshwater in rivers, lakes and glaciers is perpetually being renewed by a process of evaporation and rainfall; some of this freshwater is stored in underground aquifers. Human activities, like deforestation, create serious changes in the hydrosphere. Once the land is denuded of vegetation, the rain erodes the soil, which is then washed into the sea.

Chemicals from industry and sewage find their way into rivers and into the sea. Water pollution thus threatens the health of communities, as all our lives depend on the availability of clean water. This once plentiful resource is now becoming rare and expensive due to pollution.

(iii) Lithosphere

- Soil, the basis for agriculture to provide us with food
- Stone, sand and gravel, used for construction
- Micronutrients in soil, essential for plant growth
- Microscopic flora, small soil fauna and fungi in soil, important living organisms of the lithosphere, which break down plant litter as well as animal waste to provide nutrients for plants

- A large number of minerals on which our industries are based
- Oil, coal and gas, extracted from underground sources. They provide power for vehicles, agricultural machinery, industry and for our homes

The lithosphere began as a hot ball of matter which formed the earth about 4.6 billion years ago. About 3.2 billion years ago, the earth cooled down considerably and a very special event took place—life began on our planet. The crust of the earth is 6–7 km thick and lies under the continents. Of the 92 elements in the lithosphere, only eight are common constituents of crystal rocks. Of these, 47% is oxygen, 28% is silicon, 8% is aluminum, and 5% is iron, while sodium, magnesium, potassium and calcium constitute 4% each. Together, these elements form about 200 common mineral compounds. Rocks, when broken down, form soil on which humans are dependent for agriculture. Their minerals are also the raw material used in various industries.

(iv) Biosphere

- Food, from crops and domestic animals, providing human metabolic requirements
- Food for all forms of life, which live as interdependent species in a community, and form food chains in nature on which humans are dependent
- Energy needs: Biomass fuelwood collected from forests and plantations, along with other forms of organic matter, used as a source of energy
- Timber and other construction materials

This is the relatively thin layer on the earth in which life can exist. Within it the air, water, rocks and soil and the living creatures form structural and functional ecological units, which together can be considered as one giant global living system, that of our earth itself. Within this framework, those characterised by broadly similar geography and climate, as well as communities of plant and animal life can be divided for convenience into different biogeographical realms. These occur on different continents. Within these, smaller biogeographical units can be identified on the basis of structural differences and functional aspects into distinctive recognisable ecosystems, which give a distinctive character to a landscape or waterscape. Their easily visible and identifiable characteristics can be described at different scales, such as those of a country, a state, a district or even an individual valley, hill range, river or lake.

The simplest of these ecosystems to understand is a pond. It can be used as a model to understand the nature of any other ecosystem and to appreciate the changes that are seen over time in any ecosystem. The structural features of a pond include its size, depth and the quality of its water. The periphery, the shallow part and the deep part of the pond, each provide specific conditions for different plant and animal communities. Functionally, a variety of cycles like the amount of water within the pond at different times of the year and the quantity of nutrients flowing into the pond from the surrounding terrestrial ecosystem, all affect the 'nature' of the pond.

Natural cycles between the spheres: All these four spheres are closely interlinked systems and are dependent on the integrity of each other. Disturbing one of these spheres affects the others.

The links between them are mainly in the form of cycles. For instance, the atmosphere, hydrosphere and lithosphere are all connected through the hydrological cycle. The water evaporating from the hydrosphere (the seas and freshwater ecosystems) forms clouds in the atmosphere. On condensing, this falls as rain, which provides moisture for the lithosphere, on which life depends. The rain also acts on rocks as an agent of erosion and over millions of years has created soil, on which plants grow. Atmospheric movements in the form of wind also break down rocks into soil. The most sensitive and complex links are those between the atmosphere, the hydrosphere and the lithosphere, on the one hand, with the millions of living organisms in the biosphere on the other. All living organisms which exist on earth live only in the relatively thin layer of the lithosphere and hydrosphere present on the surface of land and in the water. The biosphere which they form has countless associations with different parts of the three other 'spheres'.

It is, therefore, essential to understand the inter-relationships of the separate entities soil, water, air and living organisms, and to appreciate the value of preserving intact ecosystems in their entirety.

Let's do it!

Observe a nearby pond in different seasons and document the seasonal changes that take place in it. One can also observe changes in a river or the seasonal changes in a forest or grassland.

Let's do it!

Take a simple object in daily use and track its components back to each of its spheres.

Example: This textbook:

- Paper from wood—the biosphere
- Water for pulping wood—the hydrosphere
- Bleach to whiten the paper—a mineral from the lithosphere

2.2 RENEWABLE AND NON-RENEWABLE RESOURCES

A renewable resource is a natural resource which, if harvested sustainably, can be regenerated after its use. Ecosystems act as resource producers and processors. Solar energy is the main driving force of ecological systems, providing energy for the growth of plants in forests, grasslands and aquatic ecosystems. A forest recycles its plant material slowly by continuously returning its dead material, leaves and branches to the soil. Grasslands recycle material much faster than forests, as the grass dries up after the rains every year. All the aquatic ecosystems also depend on solar energy and have cycles of growth when plant life spreads and aquatic animals breed; the sun also drives the water cycle.

It is important to understand that although water and biologically living resources such as forests, grasslands and wetlands are considered renewable, they are, in fact, renewable only within a certain limit. If over-utilised and/or degraded beyond that limit, they lose their capacity to regenerate.

Non-renewable resources on the other hand are natural resources that take millions of years to regenerate and are therefore irreplaceable after consumption. They are often present in only a fixed amount and are often consumed at a faster rate than the environment's capacity to regenerate them. Fossil fuels such as coal, petroleum and natural gas are some examples of non-renewable resources.

2.2.1 Natural Resources and Associated Problems

Natural resources include those resources that are derived from the environment. Water, air, minerals, oil and products gained from forests are some examples of natural resources.

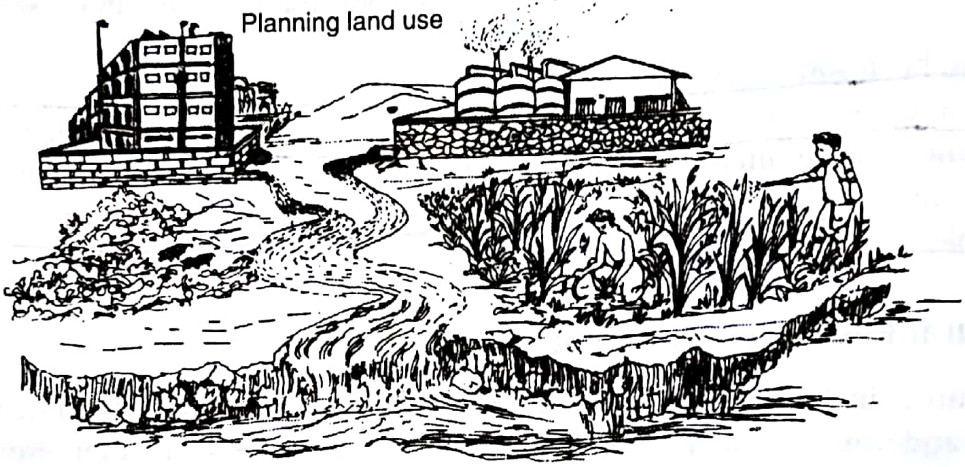
The unequal consumption of natural resources

Currently, a major part of our natural resources are consumed in the technologically advanced or 'developed' world, usually termed as 'the North'. The 'developing nations' of 'the South', including India and China, also overuse many resources because of their greater human population. However, the consumption of resources per capita (per individual) of the developed countries is up to 50 times greater than in most developing countries. Advanced countries also produce over 75% of the global industrial waste and greenhouse gases (GHGs).

Energy from fossil fuels is consumed in much greater quantities in developed countries. Their per capita consumption of food and other products is also much greater, resulting in larger quantities of waste, such as packaging material used in the food industry. Producing animal food for human consumption requires more land than that required for growing crops. Thus, countries that are highly dependent on meat-based diets need much larger areas for pasture than those where the people are mainly vegetarian. This consumption pattern can also be measured in terms of a nation or city's *Ecological Footprint* (EF), which is a measure of human demand on the earth's resources in relation to the earth's capacity to regenerate those resources. Thus, the per capita EF provides a means to compare consumption and lifestyles while checking this against the earth's ability to provide for this consumption. As of 2006, the US footprint per capita was 9.0 global hectares (gha), while India's was 0.8 gha. While India's footprint is much smaller than the world average of 2.2 gha, it is important to know that our footprint has doubled since the 1960s due to population growth. This accelerated degradation of our natural capital is unsustainable.

Planning land use

Land itself is a most important resource; it is necessary for food production, animal husbandry, industry and for our growing human settlements. These forms of intensive land use are frequently extended at the cost of 'wild lands'—our remaining forests, grasslands, wetlands and deserts. Thus, it is essential to evolve a rational land use policy that examines how much land must be made available for different purposes and where it must be situated. For instance, there are usually alternate sites at which industrial complexes or dams can be built, but a natural wilderness cannot be recreated artificially. Scientists today believe that at least 10% of the land and water bodies of each ecosystem must be kept as wilderness for the long-term needs of protecting nature and natural resources.



Land as a resource is now under serious pressure due to an increasing 'land hunger'—to produce sufficient quantities of food for an exploding human population. It is also affected by degradation due to misuse. Land and water resources are also polluted by industrial waste and rural and urban sewage, apart from being diverted for short-term economic gains to agriculture and industry. Natural wetlands of great value are being drained for agriculture and other purposes and semi-arid land is being irrigated and overused.

The most damaging change in land use is demonstrated by the rapidity with which forests have vanished in recent times, both in India and in the rest of the world. In the long term, the loss of forests and the services they provide is far greater than the short-term gains produced by converting forested lands to other uses.

The need for sustainable lifestyles

The quality of human life and the quality of ecosystems on earth are indicators of the sustainable use of resources. There are some clear indicators of sustainable lifestyles in human life, such as:

- increased longevity,
- an increase in knowledge, and
- an enhancement of income.

These three together are known as the 'Human Development Index'.

The indicators of the quality of the ecosystems are more difficult to assess. They are:

- a stabilised population or the percentage of species loss,
- species diversity in ecosystems, and
- the state of 'naturalness' of ecosystems.

Let's do it!

Utilisation of Resources

The use of a resource begins with its collection, its processing into a useable product, and transport through a delivery system to the consumer who uses it. It also involves disposal of the waste products produced at each step. Each step in resource use can affect the environment for better or worse. Control of these steps is known as environmental management.

Think of a resource you use and track it through these steps.

Example: The cotton in the clothes you are wearing. At each step, note:

- What other resources are needed at this step to move the resource you chose to the next?
- What waste products are generated at that step?
- How are they likely to be disposed of?
- What pollutants are generated in the process?

2.2.2 Renewable Resources

(i) Forest Resources

People who live in or near forests know the value of forest resources first-hand, because their lives and livelihoods depend directly on these resources. However, the rest of us also derive great benefits from the forests, which we are rarely aware of. The water we use depends on the existence of forests on the watersheds around river valleys. Our homes, furniture and paper are made from wood from the forest. We use many medicines that are based on forest produce and we depend on plants for the oxygen they emit and to remove the carbon dioxide we breathe out from the air.

Once upon a time, forests extended over large tracts of our country. People have used forests in our country for thousands of years. With the spread of agriculture, however, the forests were left in patches which were controlled mostly by tribal people. They hunted animals and gathered plants and lived entirely on forest resources. Deforestation became a major concern in British times when a large amount of timber was extracted for building ships. This led the British to develop scientific forestry in India. They, however, alienated local people by creating *Reserved* and *Protected Forests*, which curtailed access to the resources. This led to a loss of stake in the conservation of the forests and to the gradual degradation and fragmentation of forests along the length and breadth of the country.

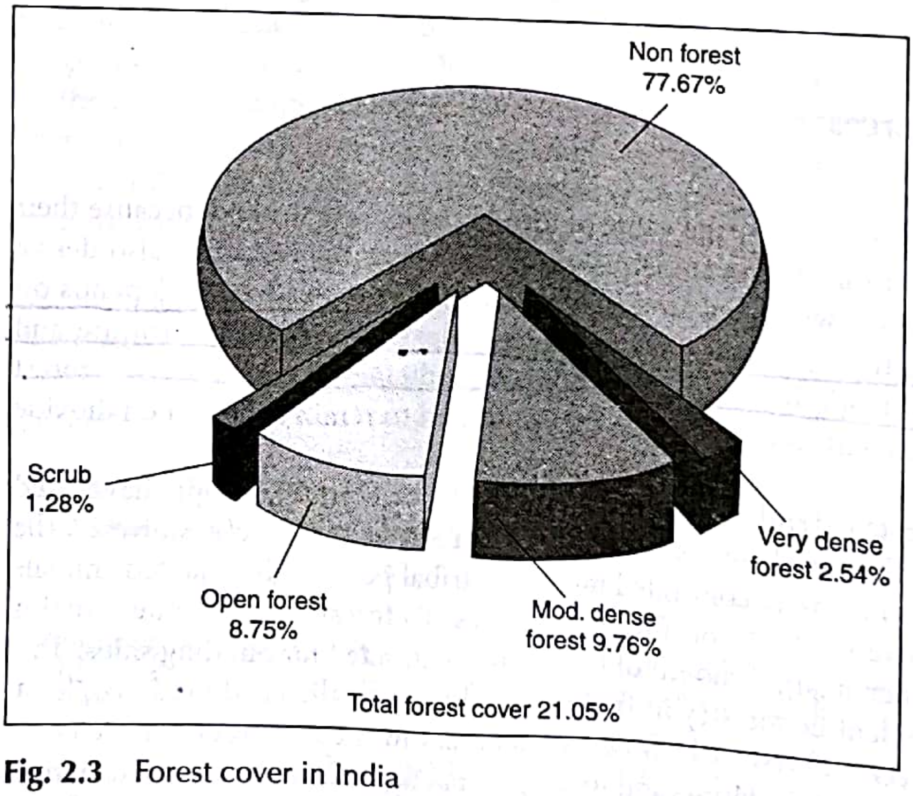
The data in Table 2.1 is represented by a pie chart for easier comprehension (Fig. 2.3).

Another period of over-utilisation and forest degradation occurred soon after India gained independence, as state sponsored agricultural expansion became a priority. The following years saw India's residual forest wealth dwindle sharply.

Table 2.1 Forest and tree cover of India in 2011

Class	Area (km²)	Geographical area (%)
Forest cover		
Very dense forest	83,471	2.54
Moderately dense forest	320,736	9.76
Open forest	287,820	
Total forest cover (includes 4662 km² under mangroves)	**692,027**	**21.05**
Tree cover	**90,844**	**2.76**
Total forest cover and tree cover	**782,871**	**23.81**
Scrub	42,177	1.28
Non-forest	2,553,059	77.67
Total geographical area	**3,287,263**	**100.0**

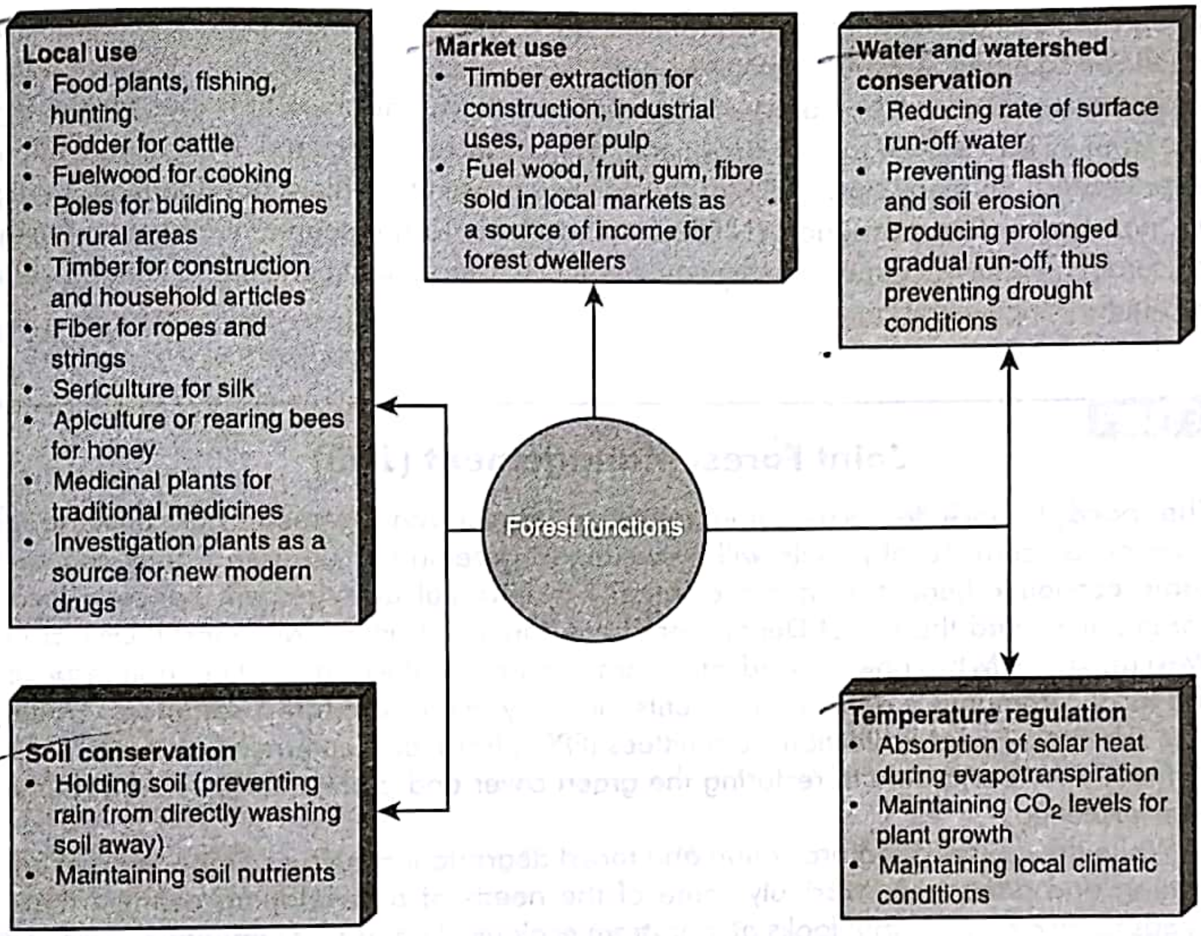
Source: India state of forest report 2011



- Very dense forest: All lands with tree canopy density of 70% and above
- Moderately dense forest: All lands with tree canopy density between 40% and 70%
- Open forest: All lands with tree canopy density between 10% and 40%
- Scrub: Degraded forest lands with canopy density less than 10%
- Non-forest: Area not included in any of the above classes.

Fig. 2.3 Forest cover in India

Forest functions include:


Local use
• Food plants, fishing, hunting
• Fodder for cattle
• Fuelwood for cooking
• Poles for building homes in rural areas
• Timber for construction and household articles
• Fiber for ropes and strings
• Sericulture for silk
• Apiculture or rearing bees for honey
• Medicinal plants for traditional medicines
• Investigation plants as a source for new modern drugs
Market use
• Timber extraction for construction, industrial uses, paper pulp
• Fuel wood, fruit, gum, fibre sold in local markets as a source of income for forest dwellers
Water and watershed conservation
• Reducing rate of surface run-off water
• Preventing flash floods and soil erosion
• Producing prolonged gradual run-off, thus preventing drought conditions
Forest functions
Soil conservation
• Holding soil (preventing rain from directly washing soil away)
• Maintaining soil nutrients
Temperature regulation
• Absorption of solar heat during evapotranspiration
• Maintaining CO2 levels for plant growth
• Maintaining local climatic conditions

Threats on forest resources: Scientists estimate that India should ideally have 33% of its land under forests. Today, we only have about 12%. Thus, we need to not only protect our existing forests but also to increase our forest cover.

Deforestation and degradation: Deforestation involves a loss in the area covered by forests. Degradation, on the other hand, refers to the condition of a forest involving a reduction in its quality. One or more of the components such as soil, vegetation and/or fauna of a forest are affected, thereby impacting the overall functioning of a forest ecosystem.

Those civilisations that looked after forests by using forest resources cautiously have prospered, whereas those that destroyed forests have gradually become impoverished. Today, expansion of agricultural land, rapid industrialisation, urbanisation, illegal logging and mining are serious causes of loss and degradation of forests in our country and all over the world. Furthermore, dams built for hydroelectric power or irrigation have submerged large tracts of forests and have displaced tribal people whose lives are closely knit to the forest. Realising this, the Ministry of Environment and Forest (MoEF) formulated the National Forest Policy of 1988 to give added importance to Joint Forest Management (JFM), which co-opts local village communities and the Forest Department to work together to sustainably manage our forests. Another resolution in 1990 provided a formal structure for community participation through the formation of

Village Forest Committees (VFCs). Based on these experiences, new JFM guidelines were issued in 2000. This stipulates that at least 25% of the income from the area must go to the community. From the initiation of the programme until 2002, there were 63,618 JFM Committees managing over 140,953 sq km of forest in 27 states in India.

Various states have tried a variety of approaches to JFM. The share of profits for the VFCs ranges from 25% in Kerala to 50% in Gujarat, Maharashtra, Orissa and Tripura and 100% in Andhra Pradesh. In many states, 25% of the revenue is used for village development. In many states, non-timber forest products (NTFPs) are available to the people free of cost. Furthermore, some states have stopped grazing while others have rotational grazing schemes that have helped in forest regeneration.

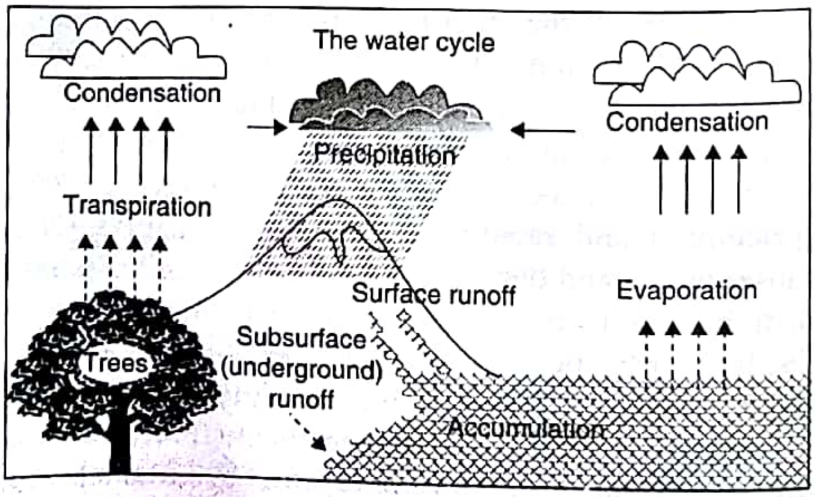
CASE STUDY 1

Joint Forest Management (JFM)

The need to include local communities in Forest Management has become a growing concern. Local people will only support greening of an area if they can see some economic benefit from conservation. An informal arrangement between local communities and the Forest Department began in 1972, in the Midnapore District of West Bengal. JFM has now evolved into a formal agreement which identifies and respects the local community's rights and benefits that they need from forest resources. Under JFM schemes, Forest Protection Committees (FPCs) from local community members are formed. They participate in restoring the green cover and protect the area from being over-exploited.

While the causes of deforestation and forest degradation such as timber extraction, mining and dams are invariably some of the needs of a developing country, there needs to be a strategy that looks at long-term ecological gains that cannot be sacrificed for short-term economic gains.

(ii) Water Resources



Fresh water (even after being used) evaporates due to the sun's energy, forms water vapor and is re-formed in clouds, which fall to earth as rain.

The water cycle, through evaporation and precipitation, maintains hydrological systems which form rivers and lakes and supports a variety of aquatic ecosystems. Wetlands are the intermediate forms between terrestrial and aquatic ecosystems and contain species of plants and animals that are highly moisture-dependent. All aquatic ecosystems are used by a large number of people for their daily needs such as drinking water, washing, cooking, watering animals and irrigating fields. However, the world depends on a limited quantity of freshwater. Water covers 70% of the earth's surface, but only 3% of this is fresh water. Of this, 2% is present as polar ice caps and only 1% is usable water in rivers, lakes and subsoil aquifers. Only a fraction of this can be actually used. At a global level, 70% of the water is used for agriculture, about 22% for industry and only 8% for domestic purposes. However, this varies in different countries, and industrialised countries use a greater percentage for industry. India uses 87% of its water for agriculture, 8% for industry and 5% for domestic purposes (National Commission for Water Resources Development Plan, Ministry of Water Resources, 1999).

One of the greatest challenges facing the world this century, is the need to rethink the overall management of water resources. Water sources can be overused or wasted to such an extent that they locally run dry. Water sources can also become so heavily polluted by sewage and toxic substances that it becomes impossible to use the water.

The world population has passed the 6 billion mark. Based on the proportion of young people in developing countries, this will continue to increase significantly during the next few decades. This places enormous demands on the world's limited freshwater supply. The total annual freshwater withdrawals today are estimated at 3800 cubic kilometres, twice as much as just 50 years ago (World Commission on Dams, 2000). Studies indicate that a person needs a minimum of 20–40 litres of water per day for drinking and sanitation. However, more than one billion people worldwide have no access to clean water, and to many more, water supplies are unreliable. Local water conflicts are already spreading to states; for example, Karnataka and Tamil Nadu are fighting over the waters of the Cauvery River and Karnataka and Andhra Pradesh over the Krishna waters.

India is expected to face critical levels of water stress by 2025. At the global level, 31 countries are already short of water and by 2025 there will be 48 countries facing serious water shortages. The UN has estimated that by the year 2050, 4 billion people will be seriously affected by water shortages. This will lead to multiple conflicts between countries over the sharing of water. Around 20 major cities in India face chronic or interrupted water shortages. There are 100 countries that share the waters of 13 large rivers and lakes. The upstream countries could starve the downstream nations, leading to political instability across the world. Examples are Ethiopia, which is upstream on the Nile, and Egypt, which is downstream and highly dependent on the Nile. International accords that will look at a fair distribution of water in such areas will become critical to world peace. India and Bangladesh already have a negotiated agreement on the use of the Ganges River.

Mismanagement and pollution of water resources: With the growth of human population, there is an increasing need for larger amounts of water to fulfil everyone's needs. Today, in many areas, this requirement cannot be met. The mismanagement of water resources has meant an inequitable distribution of water—some use more water than they need while others do not have access to clean water at all.

Agriculture also pollutes surface water and underground water stores by the excessive use of chemical fertilisers and pesticides. Methods, such as the use of biomass as fertiliser and non-toxic pesticides such as neem products, and using integrated pest management systems, all help reduce the agricultural pollution of surface and ground water. There are many ways in which farmers can use less water without reducing yield, such as by using the drip irrigation system.

Industries also tend to overlook their environmental impact while maximising their short-term economic gains. Industrial liquid waste is often released into streams, rivers and the sea unchecked. Public awareness may increasingly put pressure on industry to produce products in a manner which minimises the impact on the environment. In the longer term, as people become more conscious of using 'green products', ecosensitive industries will gain a greater competitive market compared with industries that continue to pollute. As people begin to learn about the serious health hazards caused by pesticides in their food, public awareness can begin putting pressure on farmers to reduce the use of chemicals that are injurious to health.

Global climate change: Changes in climate at a global level, caused by increasing air pollution, have now begun to affect our climate. In some regions, global warming and the *El Niño winds* have created unprecedented storms. In other areas, they lead to long droughts. Everywhere, the 'greenhouse effect' due to atmospheric pollution is leading to increasingly erratic and unpredictable climatic effects. This has seriously affected regional hydrological conditions.

Floods: Floods have been a serious environmental hazard for centuries. However, the havoc caused by rivers overflowing their banks has become progressively more damaging, as people have deforested catchments and intensified the use of river flood-plains that once acted as safety valves. The wetlands in flood-plains are nature's flood control systems into which overfilled rivers could spill and they act like a temporary sponge holding the water and preventing fast-flowing water from damaging the surrounding land.

Floods

Deforestation in the Himalayas causes floods that year after year kill people, damage crops and destroy homes along the Ganges and Brahmaputra and their tributaries. Rivers change their course during floods and tons of valuable soil is lost to the sea. As the forests are degraded, rainwater no longer percolates slowly into the subsoil but runs off down the mountainside, bearing large amounts of topsoil. This blocks or 'silts' up the rivers temporarily, but eventually gives way as the pressure mounts, allowing enormous quantities of water to suddenly wash down into the plains below. There, the rivers swell, burst their banks and flood waters spread to engulf peoples' farms and homes.

Drought: In most arid regions of the world, the rains are very unpredictable. This leads to periods when there is a serious scarcity of water to drink, use in farms or provide for urban and industrial use. Drought-prone areas are thus faced with irregular periods of famine. Agriculturists have no income in these years and as they have no steady income, they have a constant fear of droughts. India has 'Drought-Prone Areas Development Programmes', which are used in such areas to buffer the effects of drought. Under these schemes, people are given wages in years of water scarcity to build roads, minor irrigation works and plantation programmes.

Drought

Drought has been a major problem in our country, especially in arid and semi-arid regions. It is an unpredictable climatic condition and occurs due to the failure of one or more monsoons. It varies in frequency in different parts of the country. While it is not feasible to prevent the monsoon from failing, good environmental management can reduce its ill-effects. The scarcity of water during drought years affects homes, agriculture and industry. It also leads to food shortage and malnutrition which especially affects children.

Several measures can be taken to minimise the serious impacts of a drought. However, this must be done as a preventive measure so that if the monsoon fails, its impact on local peoples' lives is reduced. In years when the monsoon is adequate, we often use up the supply of water without trying to conserve it or use it judiciously. Thus, in a year when the rains are poor, there is no water even for drinking in the drought areas.

One factor that aggravates the effect of drought is deforestation. Once the hill-slopes are denuded of forest cover, the rainwater rushes down the rivers and is lost. Forest cover permits water to be held in the area and gradually seep into the ground. This charges the underground stores of water in natural aquifers. This can be used in drought years if the stores have been filled during a good monsoon. If water from the underground stores is overused, the water table drops and vegetation suffers. This soil and water management and afforestation are long-term measures that reduce the impact of drought.

Water for agriculture and power generation: India's increasing demand for water for intensive irrigated agriculture, for generating electricity and for consumption in urban and industrial centres, has been met by creating large dams. The area under irrigation has increased from 40 million ha in 1900 to 100 million ha in 1950 and to 271 million ha by 1998. Dams support 30%–40% of this area.

Although dams ensure a year-round supply of water for domestic use and provide extra water for agriculture, industry and hydropower generation, they are also accompanied by several serious environmental problems. They alter river flows, change nature's flood-control mechanisms, such as wetlands and flood-plains, and destroy the lives of local people and the habitats of wild plant and animal species. Intensive irrigation to support water-hungry cash crops like sugarcane produces an unequal distribution of water. Large landholders on the canals get the lion's share of water, while smaller farmers get less and are adversely affected.

Dams: Managing a river system is best done by leaving its course undisturbed. Dams and canals lead to major floods during the monsoons and drainage of wetlands seriously affects the areas that get flooded when there is high rainfall.

Today there are more than 45,000 large dams around the world, which play an important role in communities and economies that harness these water resources for their economic development. Current estimates suggest that about 30%–40% of the irrigated land worldwide relies on dams. Hydropower, another contender for the use of stored water, currently supplies 19% of the world's total electric power supply and is used in over 150 countries. The world's two most populous countries, China and India, have built around 57% of the world's largest dams (World Commission on Dams, International Rivers Organization, 2008).

Problems caused by dams

- The fragmentation and physical transformation of rivers
- Serious impact on riverine ecosystems
- Social consequences of large dams due to the displacement of people
- Water-logging and salinisation of the surrounding lands
- Dislodging animal populations, damaging their habitat and cutting off their migratory routes

- Disruption of fishing and waterway traffic
- The emission of greenhouse gases from reservoirs due to rotting vegetation and carbon inflows from the catchment is a recently identified impact

Large dams have had a serious impact on the lives, livelihoods, cultures and spiritual existence of indigenous and tribal people. They have suffered disproportionately from the negative impact of dams and have often been excluded from sharing the benefits. In India, of the 16–18 million people displaced by dams, 40%–50% are tribal people, who account for only 8% of our nation's one billion people.

Conflicts over dams have heightened over the last two decades because of their social and environmental impact and failure to achieve targets for adhering to costs as well as achieving promised benefits. Recent examples show how the failure to provide a transparent process that includes the effective participation of local people has prevented these people from playing an active role in debating the pros and cons of the project and its alternatives. The loss of traditional and local controls over equitable distribution remains a major source of conflict.

In India, a national assessment of dam projects cleared in the 1980s and '90s shows that in 90% of the cases, the project authorities have not fulfilled the environmental conditions under which environmental clearance was given by the GOI under the EPA of 1986.

CASE STUDY 2

Sardar Sarovar project

This project is a multi-purpose dam project built in the Narmada River Valley. It has impacted millions of people living in the river valley. The farmers downstream will get water for agriculture at the cost of the tribal folk, farmers and fishermen at the estuary who have lost their homeland and their means of livelihood. The question is why should the local tribals be rendered homeless, displaced and relocated to benefit other people? Why should the less fortunate be made to bear the costs of development for wealthier farmers? It is a question of social and economic equity as well as the enormous environmental losses, including loss of the biological diversity of the inundated forests in the Narmada Valley.

'Save water' campaigns are essential to make people everywhere aware of the dangers of water scarcity. A number of measures need to be taken for better management of the world's water resources. These include measures such as:

- building several small reservoirs instead of a few mega projects,
- developing small catchment dams and protecting wetlands,
- soil management, micro-catchment development and afforestation, which enables recharging of underground aquifers, thus reducing the need for large dams,
- treating and recycling municipal waste water for agricultural use,
- preventing leakages from dams and canals,
- preventing loss in municipal pipes,
- effective rainwater harvesting and recharging of groundwater in urban environments,
- water conservation measures in agriculture, such as using drip irrigation,
- pricing water at its real value, which makes people use it more responsibly and efficiently and reduces wastage, and

- in deforested areas where land has been degraded, soil management, by making *bunds* along the hill-slopes and making *nalla* plugs, can help retain moisture and make it possible to revegetate degraded areas.

Sustainable water management is a crucial step towards the world's looming water crisis situation.

Let's do it!

How much water does one person need a day? Several international agencies and experts have proposed that 50 litres per person per day covers the basic human water requirements for drinking, sanitation, bathing and food preparation. Estimate your average daily consumption.

(iii) Mineral Resources

A mineral is a naturally occurring substance of definite chemical composition and identifiable physical properties. An ore is a mineral or combination of minerals from which a useful substance, such as a metal, can be extracted and used to manufacture useful products.

Minerals are formed over a period of millions of years in the earth's crust. Iron, aluminum, zinc, manganese and copper are important raw materials for industrial use. Important non-metallic resources include coal, salt, clay, cement and silica. Stone used for building material, such as granite, marble and limestone, constitute another category of minerals. Minerals with special properties that humans value for their aesthetic and ornamental value are gems such as diamonds, emeralds and rubies. The lustrous metals such as gold, silver and platinum are used for ornaments. Minerals in the form of oil, gas and coal were formed when ancient plants and animals were converted into underground fossil fuels.

Iron ore mine

Minerals and their ores need to be extracted from the earth's interior so that they can be used; this process is known as mining. Mining operations generally progress through four stages.

- Prospecting: Searching for minerals.
- Exploration: Assessing the size, shape, location and economic value of the deposit.
- Development: The work of preparing access to the deposit so that the minerals can be extracted from it.
- Exploitation: Extracting the minerals from the mines.

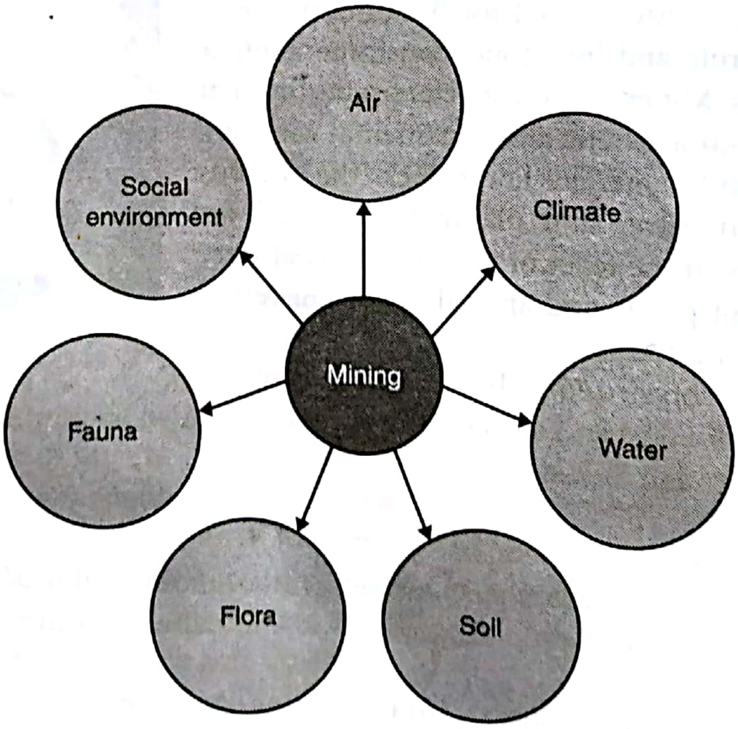
In the past, mineral deposits were discovered by prospectors in areas where deposits in the form of veins were exposed on the surface. Today, however, prospecting and exploration is done by teams of geologists, mining engineers, geophysicists, and geochemists, who work together to discover new deposits. Modern prospecting methods include the use of sophisticated instruments, like GIS, to survey and study the geology of the area and discover placers. The method of mining has to be determined depending on whether the ore or mineral deposit is nearer the surface or deep within the earth. The topography of the region and the physical nature of the ore deposit are also studied.

Mines are of two types—surface (open-cast or strip mines) or deep (or shaft) mines. Coal, metals and non-metalliferous minerals are all mined differently depending on the above criteria. The method chosen for mining will ultimately depend on how the maximum yield may be obtained under existing conditions at the minimum cost, with the least danger to the mining personnel.

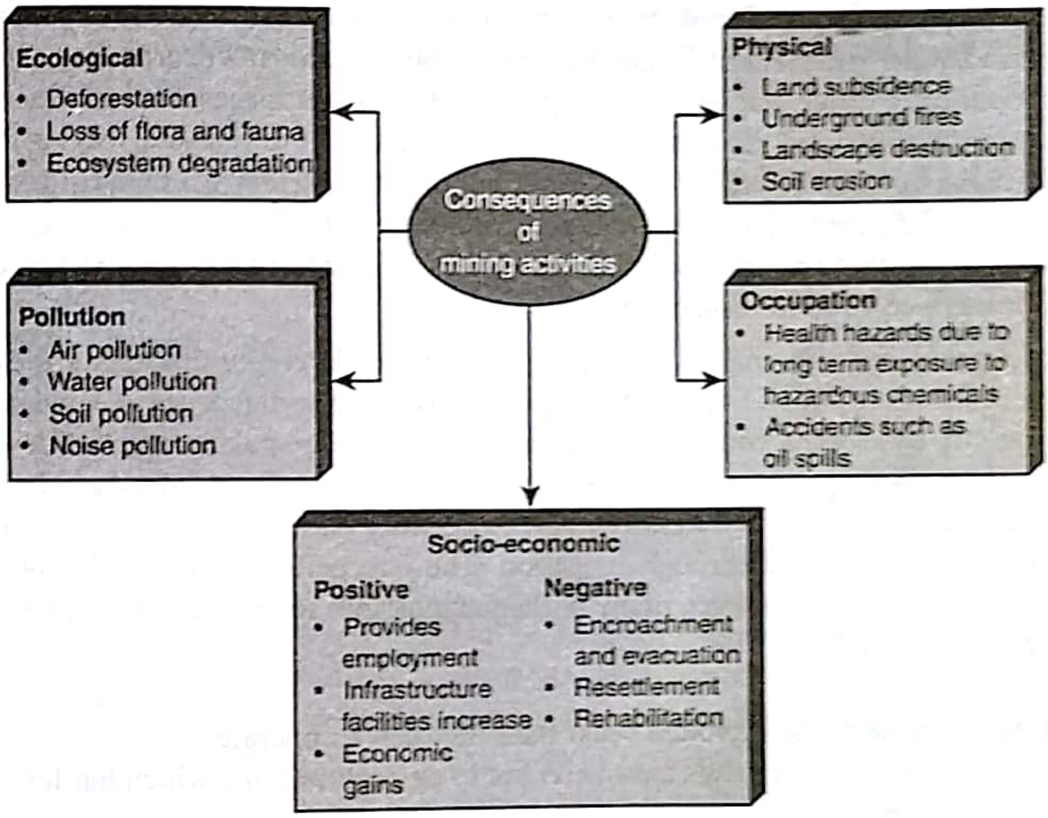
Most minerals need to be processed before they become usable. Thus, 'technology' is dependent on both the presence of resources and the energy necessary to make them 'usable'.

Mine safety: Mining is a hazardous occupation, and the safety of mine workers is an important environmental consideration. Surface mining is less hazardous than underground mining, and metal mining is less hazardous than coal mining. In all underground mines, rock- and roof-falls, flooding and inadequate ventilation are the greatest hazards. Large explosions have occurred in coal mines, killing many miners. More miners have suffered from disasters due to the use of explosives in metal mines.

Mining poses several long-term occupational hazards to the miners. The dust produced during mining operations is injurious to health and causes a lung disease known as 'black lung' or pneumoconiosis. The fumes generated by incomplete dynamite explosions are extremely poisonous. Methane gas, emanating from coal strata, is hazardous to health, although not poisonous in the concentrations usually encountered in mine air. Radiation is a life-threatening hazard in uranium mines.



Environmental problems: Mining operations are considered one of the main sources of environmental degradation. The extraction of all these products from the lithosphere has a variety of side effects. The depletion of available land due to mining, waste from industries, conversion of land to industry and pollution of land, water and air by industrial waste are the environmental side effects of the use of these non-renewable resources. There is global public awareness of this problem and government actions to stem the damage to the natural environment have led to numerous international agreements and laws directed toward the prevention of activities and events that may adversely affect the environment.



CASE STUDY 3

Sariska Tiger Reserve, Rajasthan

STPR

The Forest Department leased land for mining in the Sariska Tiger Reserve area by denotifying the protected forest areas. The local people fought against the mining lobby, and filed a Public Interest Litigation (PIL) in the Supreme Court in 1991. As a result, the Supreme Court banned mines in the core zone of the reserve. However, more recently, the Sariska Tiger Reserve has been faced with threats of illegal poaching. This is further discussed in Unit 4.

Let's do it!

A coal mining company is to commence operations in a small farming town in Maharashtra. Form two discussion groups in your class: Group A is the mining company that will list out the positive impacts of having this operation in town. Group B represents the concerned public that will list out the negative impacts of having this operation. Discuss and come up with a decision/solution.

(iv) Food Resources

Today our food comes almost entirely from agriculture, animal husbandry and fishing. India is self-sufficient in food production; however, this has come at a cost. The modern practice of intensive agriculture pollutes our waterways and land with excessive use of fertilisers and pesticides.

The FAO (Food and Agricultural Organization) defines sustainable agriculture as that which conserves land, water and plant and animal genetic resources, does not degrade the environment and is economically viable and socially acceptable. Most of our large farms grow single crops (monoculture). If this crop is hit by a pest, the entire crop can be devastated, leaving the farmer with no income during the year. On the other hand, if the farmer uses traditional varieties and grows several different crops, the chance of complete failure is lowered considerably. Many studies have shown that one can use alternatives to inorganic fertilisers and pesticides. This is known as Integrated Crop Management.

World food problems: In many developing countries where populations are expanding rapidly, the production of food is unable to keep pace with the growing demand. Food production in 64 of the 105 developing countries is lagging behind their population growth levels. These countries are unable to produce more food, or do not have the financial means to import it. India is one of the countries that has been able to produce enough food by cultivating a large proportion of its arable land through irrigation. The Green Revolution of the '60s reduced starvation in the country. However, many of the technologies we have used to achieve this are now being questioned.

- Our fertile soils are being exploited faster than they can recuperate.
- Forests, grasslands and wetlands have been put to agricultural use, which has led to serious ecological consequences.
- Our fish resources, both marine and inland, show evidence of exhaustion.
- There is great disparity in the availability of nutritious food. Some communities such as tribal people still face serious food problems leading to malnutrition, especially among women and children.

These issues raise new questions as to how demands will be met in the future, even with a slowing down of population growth. Today, the world is seeing a changing trend in dietary habits. As living standards are improving, people are eating more meat-based food. As people change from eating grain to meat, the world's demand for feed for livestock, based on agriculture, increases as well. This uses more land per unit of food produced and the result is that the world's poor do not get enough to eat.

Women play a vital role in food production as well as in cooking meals and feeding children. In most rural communities, they have the least exposure to technical training and to health workers trained in teaching/learning on issues related to nutritional aspects. Women and girls frequently receive less food than the men. These disparities need to be corrected.

In India there is a shortage of cultivable productive land. Thus, farms are too small to support a family on farm produce alone. With each generation, farms are being subdivided further. Poor environmental agricultural practices such as slash-and-burn, shifting cultivation or *rab* (woodash) cultivation degrade the forests. Globally, 5–7 million ha of farmland is degraded each year. The loss of nutrients and the overuse of agricultural chemicals are major factors in land degradation. Water scarcity is an important aspect of poor agricultural output. Salinisation and water-logging has affected a large amount of agricultural land worldwide.

Food security: It is estimated that 18 million people worldwide, most of whom are children, die each year due to starvation or malnutrition, and many others suffer a variety of dietary deficiencies. The earth can only supply a limited amount of food. If the world's carrying capacity to produce food cannot meet the needs of a growing population, anarchy and conflict will follow. Thus, food security is closely linked with population control through the family welfare program. It is also linked to the availability of water for farming. Food security is only possible if food is equitably distributed to all. Many of us waste a large amount of food carelessly. This eventually places great stress on our environmental resources.

Another major concern is the support needed for small farmers so that they remain farmers rather than shifting to urban centres as unskilled industrial workers. International trade policies with regard to an improved flow of food across national borders from those who have surplus to those who have a deficit in the developing world is another issue that is a concern for planners who deal with international trade concerns. 'Dumping' of under-priced foodstuff produced in the developed world onto markets in undeveloped countries undermines crop prices and forces farmers there to adopt unsustainable practices in order to compete.

Fisheries: Fish is an important source of protein for many people. This includes both marine and freshwater fish. While the supply of food from fisheries has increased phenomenally between 1950 and 1990, in several parts of the world, the fish catch has dropped due to overfishing. In 1995, the FAO reported that 44% of the world's fisheries are fully or heavily exploited—16% are already overexploited, 6% are depleted and only 3% are gradually recovering. Canada had to virtually close down cod fishing in the 1990s due to the severe depletion of its fish reserves.

Modern fishing technology using mechanised trawlers and small meshed nets have lead directly to overexploitation, which is not sustainable. It is evident that fish have to breed successfully and need to have time to grow if the yield has to be used sustainably. The small traditional fishermen, who are no match for organised trawlers, are the worst affected by these developments.

Loss of genetic diversity: There are 50,000 known edible plants documented worldwide. Of these, only 15 varieties produce 90% of the world's food. Modern agricultural practices have resulted in a serious loss of genetic variability of crops. India's distinctive traditional varieties of rice alone are said to have numbered between 30 and 50,000. Most of these have been lost to the farmer during the last few decades, as multinational seed companies aggressively push a few commercial genotypes.

This creates a risk to our food security, as farmers can lose all their produce due to a rapidly spreading disease. On the other hand, a cereal that has multiple varieties growing in different locations does not permit the rapid spread of a disease.

The most effective method to introduce desirable traits into crops is by using characteristics found in the wild relatives of crop plants. As the wilderness shrinks, these varieties are rapidly disappearing. Once they are completely lost, their desirable characteristics cannot be introduced when found necessary in the future. Ensuring long-term food security may depend on conserving the wild relatives of crop plants in national parks and wildlife sanctuaries.

If plant genetic losses worldwide are not slowed down, some estimates show that as many as 60,000 plant species, which account for 25% of the world's total, will be lost by the year 2025. The most economical way to prevent this is by expanding the network and coverage of our protected areas. Collections in germplasm, seed banks and tissue culture facilities are other possible ways to prevent extinction, but these are extremely expensive.

Scientists now believe that the world will soon need a second Green Revolution to meet our future demands of food, based on a new ethic of land and water management that must incorporate values which include environmental sensitivity, equity, biodiversity conservation of cultivars and *in-situ* preservation of wild relatives of crop plants. This must not only provide food for all, but also enable a more equitable distribution of both food and water, reduce agricultural dependence on the use of fertilisers and pesticides (which have long-term ill-effects on human wellbeing) and provide increasing support for preserving wild relatives of crop plants in protected areas. The pollution of water sources, land degradation and desertification must be rapidly reversed. Adopting soil conservation measures, using appropriate farming techniques, especially on hill-slopes, enhancing the soil with organic matter, rotating crops and managing watersheds at the micro-level are the keys to agricultural production to meet future needs. Most importantly, food supply is closely linked to the effectiveness of population control programs worldwide. The world needs better and more sustainable methods of food production, which is an important aspect of land use management.

Alternate food sources: Food can be innovatively produced if we break out of current agricultural patterns. This includes working on new avenues to produce food, such as using forests for their multiple non-wood forest products, which can be used for food if harvested sustainably. This includes fruits, mushrooms, sap, gum and others. This will, of course, take time, as people must develop a taste for these new foods.

Medicines, both traditional and modern, can be harvested sustainably from forests. Madagascar's Rosy Periwinkle used for childhood leukemias and Taxol obtained from Western Yew from the American North-west as an anti-cancer drug are examples of forest products used extensively in modern medicine. Without due care, commercial exploitation can lead to the early extinction of such plants.

CASE STUDY 4

Using wastewater

In India, some traditional communities in urban and semi-urban towns used to grow their own vegetables in backyards, using wastewater from their own homes. Kolkata releases its wastewater into surrounding lagoons in which fish are reared and the water is also used for growing vegetables.

Using unfamiliar crops such as *Nagli*, which are grown on poor soil on hill-slopes, is another option. This crop, found in the Western Ghats, has no market at present and is thus rarely grown. Only local people use this nutritious crop. Therefore, it is not as extensively cultivated as in the past. Popularising this crop could add to food availability from marginal lands. Several crops can be grown in urban settings, including vegetables and fruit, which can be grown on waste household water and fertilisers from vermicomposting pits.

Several foods can be popularised from yet unused seafood products like seaweed, as long as this is done at sustainable levels. Educating women, who are more closely involved with feeding the family, about nutrition is an important aspect of supporting the food needs of many developing countries.

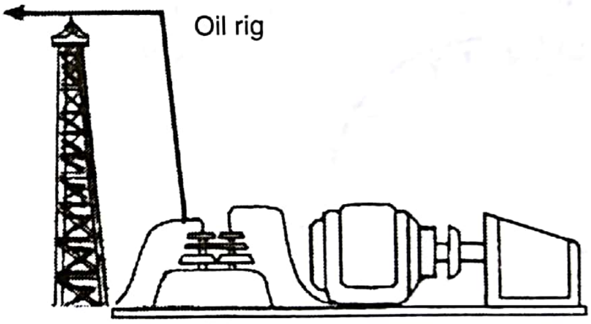
Integrated Pest Management which includes preserving pest predators, using pest-resistant seed varieties and reducing the use of chemical fertilisers, should also be adopted for sustainable food production.

(v) Energy Resources

Energy is defined by physicists as the capacity to do work. Energy is found on our planet in a variety of forms, some of which are immediately useful, while others require a process of transformation.

The sun is the primary source of energy. We use it directly for its warmth and through various natural processes that provide us with food, water, fuel and shelter. The sun's rays power the growth of plants, which form our food material, give off oxygen which we breathe in and take up carbon dioxide that we breathe out. The sun's energy evaporates water from oceans, rivers and lakes, to form clouds that turn into rain. Today's fossil fuels were once the forests that grew in prehistoric times due to the energy of the sun.

The chemical energy present in chemical compounds is released when they are broken down by animals in the presence of oxygen. In India, manual labour is still extensively used to get work done in agricultural systems, and domestic animals used to pull carts and ploughs. Electrical energy is produced in several ways—power transport, artificial lighting, agriculture and industry. This comes from hydel power based on the water cycle that is powered by the sun's energy that supports evaporation, or from thermal power stations powered by fossil fuels. Nuclear energy is held in the nucleus of an atom and is now harnessed to develop electrical energy.



We use energy for household purposes, agriculture, production of industrial goods and for transportation. Modern agriculture uses chemical fertilisers, which require large amounts of energy for their manufacture. Industry uses energy to power manufacturing units and the urban complexes that support it. Energy-demanding roads and railway lines are built to transport products from place to place and to reach raw materials in mines and forests.

No energy-related technology is completely 'risk free' and unlimited demands on energy increase this risk factor many-fold. All energy use creates heat and contributes to atmospheric temperature. In addition, many forms of energy release carbon dioxide and lead to global warming.

At present, almost 2 billion people worldwide have no access to electricity at all. While more people will require electrical energy, those who do have access to it continue to increase their individual requirements. In addition, a large proportion of energy from electricity is wasted during transmission as well as at the user level. It is broadly accepted that long-term trends in energy use should be towards a cleaner global energy system that is less carbon intensive and less reliant on finite non-renewable energy sources. It is estimated that the current methods of using renewable energy and non-renewable fossil fuel sources together will be insufficient to meet foreseeable global demands for power generation beyond the next 50–100 years.

Thus, when we use energy wastefully, we are contributing to the environmental deterioration of our planet. We all need to become responsible energy users. Remember that even a single electrical light that is burning unnecessarily is a contributor to environmental degradation!

Growing energy needs: Energy has always been closely linked to man's economic growth and development. The present strategies for development, focussed on rapid economic growth, have used energy utilisation as an index of economic development. This index, however, does not take into account the adverse long-term effects of excessive energy utilisation on society.

Between 1950 and 1990, the world's energy needs increased four-fold. The world's demand for electricity has doubled over the last 22 years! The world's total primary energy consumption in 2000 was 9096 million tons of oil; a global average per capita that works out to be 1.5 tons of oil. Electricity is at present the fastest growing form of end-use energy worldwide. By 2005, the Asia–Pacific region is expected to surpass North America in energy consumption, and by 2020 is expected to consume some 40% more energy than North America.

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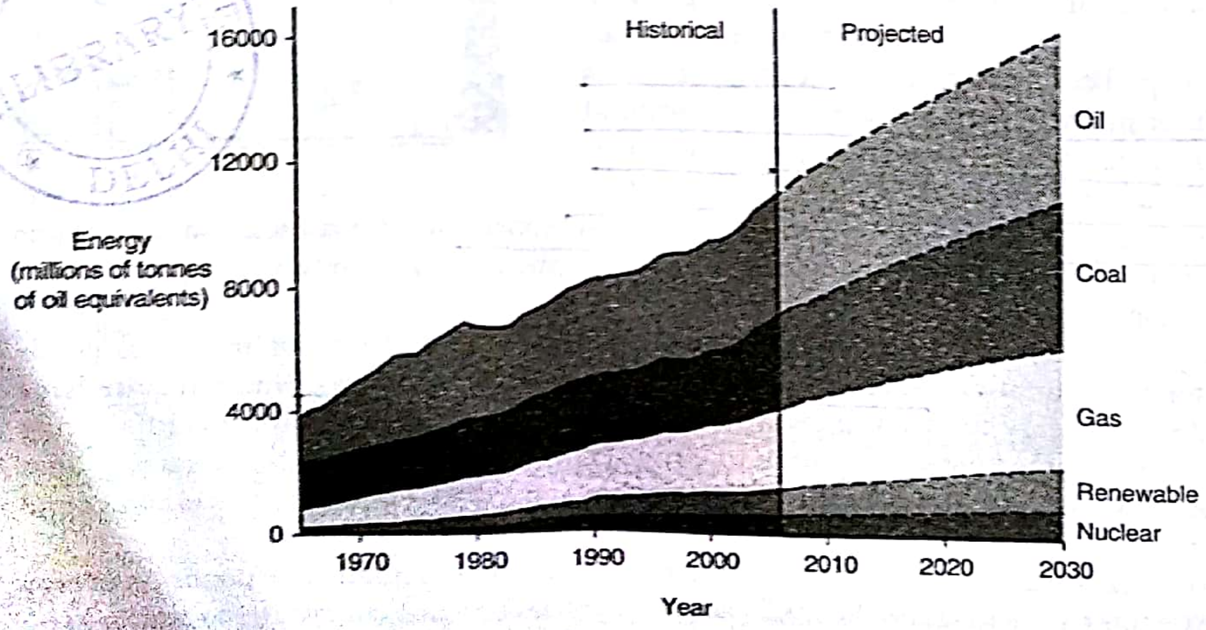

Fig. 2.4 Energy demand by fuel type
Source: International Energy Agency (Power generation from coal) 2011

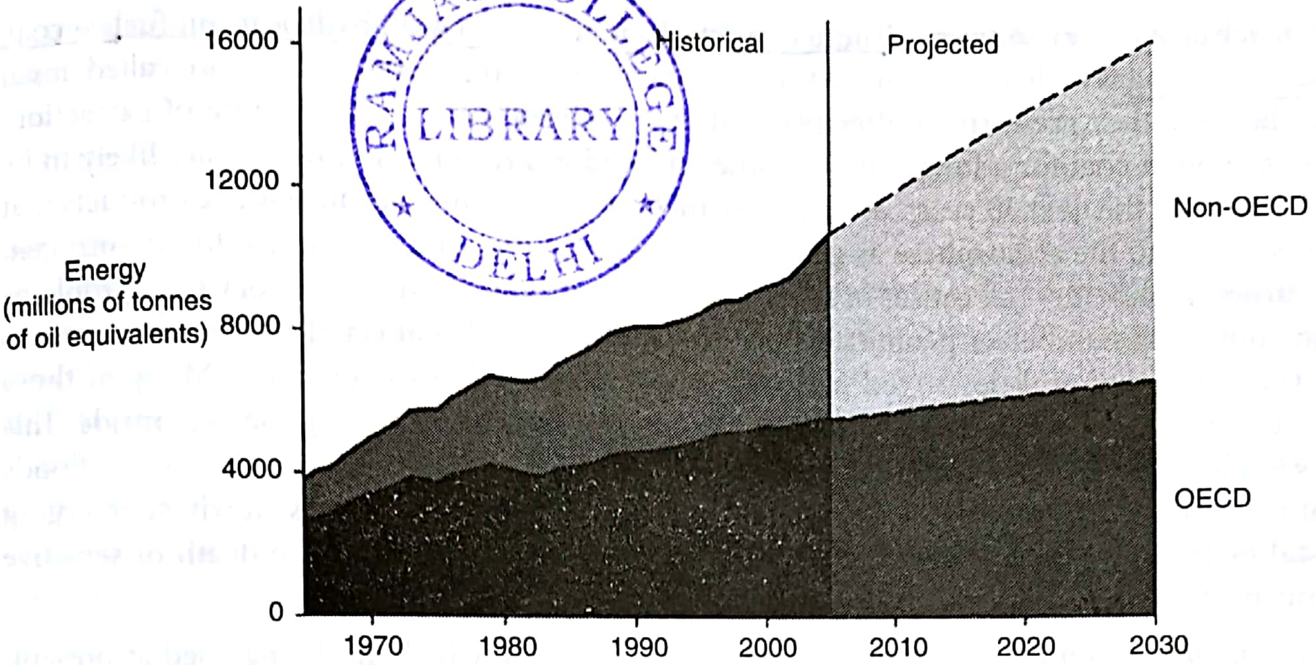

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Fig. 2.5 World energy consumption: OECD vs. non-OECD

Source: International Energy Agency (Power generation from coal) 2011

OECD: Organisation for Economic Co-operation and Development is an international organisation of 34 countries to help economic progress and world trade. Some of the OECD countries include Australia, New Zealand, Belgium, Austria, Germany, South Korea, Japan, United Kingdom, United States of America. Some of the non-OECD countries include Brazil, China, Colombia, India, South Africa.

For almost 200 years, coal was the primary energy source, fuelling the Industrial Revolution in the 19th century. At the close of the 20th century, oil accounted for 39% of the world's commercial energy consumption, followed by coal (24%) and natural gas (24%), while nuclear (7%) and hydro/renewable power sources (6%) accounted for the rest.

Among the commercial energy sources used in India, coal is a predominant source, accounting for 55% of energy consumption estimated in 2001, followed by oil (31%), natural gas (8%), hydro (5%) and nuclear power (1%). In India, biomass (mainly wood and dung) accounts for almost 40% of the primary energy supply. While coal continues to remain the dominant fuel for electricity generation, nuclear power has been used increasingly since the 1970s and 1980s, and the use of natural gas increased rapidly in the '80s and '90s.

Types of energy: There are three main types of energy: those classified as non-renewable; those that are said to be renewable; and nuclear energy, which uses such small quantities of raw material (uranium) that supplies are, to all effect, limitless. However, this classification is inaccurate because several of the renewable sources, if not used 'sustainably', can be depleted more quickly than they can be renewed.

Non-renewable energy

To produce electricity from non-renewable resources, the material must first be ignited. The fuel is placed in a secured area and set on fire. The heat thus generated turns water to steam, which moves through pipes, to turn the blades of a turbine. This converts magnetism into electricity, which we use in various appliances.

Non-renewable energy sources: These consist of the mineral-based hydrocarbon fuels – coal, oil and natural gas – that were formed from ancient prehistoric forests. These are called 'fossil fuels', because they are formed after plant life is fossilised. At the present rate of extraction, there is enough coal for a long time to come. Oil and gas resources, however, are likely to be used up within the next 50 years. When these fuels are burnt, they produce waste products that are released into the atmosphere as gases such as carbon dioxide, oxides of sulphur, nitrogen, and carbon monoxide—all causes of air pollution. These have led to respiratory tract problems in an enormous number of people all over the world, have also affected historic monuments like the Taj Mahal and destroyed many forests and lakes due to acid rain. Many of these gases contribute to the greenhouse effect, letting sunlight in and trapping the heat inside. This leads to global warming, a rise in global temperature, increased drought in some areas, floods in other regions, the melting of icecaps and a rise in sea levels, which is slowly submerging coastal belts all over the world. The warming of the seas also leads to the death of sensitive organisms like coral.

Oil and its impact on the environment: India's oil reserves, which are being used at present, lie off the coast of Mumbai and in Assam. Most of our natural gas is linked to oil and, because there is no distribution system, it is just burnt off. This means that nearly 40% of available gas is wasted. The processes of oil and natural gas drilling, processing, transport and utilisation have serious environmental consequences, such as leaks in which air and water are polluted and accidental fires that may go on burning for days or weeks before they are put out. While refining oil, solid waste like salts and grease are produced, which also damage the environment. Oil slicks are caused at sea from offshore oil wells, cleaning of oil tankers and shipwrecks. The most well-known disaster occurred when the huge oil-carrier, the *Exxon Valdez* sank in 1989 and birds, sea otters, seals, fish and other marine life along the coast of Alaska was seriously affected.

Oil-powered vehicles emit carbon dioxide, sulphur dioxide, nitrous oxide, carbon monoxide and particulate matter that are a major cause of air pollution, especially in cities with heavy traffic density. Leaded petrol leads to neurological damage and reduces attention span. Petrol vehicles can be run with unleaded fuel by attaching catalytic converters to all new cars, but unleaded fuel contains benzene and butadiene which are known to be carcinogenic compounds. Delhi, which used to have a serious smog problem due to traffic, has been able to reduce this health hazard by changing a large number of its vehicles to CNG, which contains methane.

This high dependence on dwindling fossil fuel resources, especially oil, results in political tension, instability and war. At present, 65% of the world's oil reserves are located in the Middle East.

Coal and its impact on the environment: Coal is the world's largest single contributor of greenhouse gases and is one of the most important causes of global warming. Many coal-based power generation plants are not fitted with devices such as electrostatic precipitators to reduce emissions of suspended particulate matter (SPM), which is a major air polluter. Burning coal also produces oxides of sulphur and nitrogen which, combined with water vapour, lead to 'acid rain'. This destroys forest vegetation, damages architectural heritage sites, pollutes water and affects human health.

Thermal power stations that use coal produce waste in the form of 'fly-ash'. Large dumps are required to dispose of this waste material; some efforts have been made to use it for making bricks. The transport of large quantities of fly-ash and its eventual dumping are costs that have to be included in calculating the cost benefits of thermal power.

Renewable energy

Renewable energy systems use resources that are constantly replaced and are usually less polluting. Some examples are: hydropower, solar, wind and geothermal (energy from the heat inside the earth). We also get renewable energy from burning trees and even garbage as fuel and processing other plants into biofuels.

One day, all our homes may get their energy from the sun or the wind. Your car's fuel tank will probably use biofuel, and your garbage might contribute to your city's energy supply. Renewable energy technologies will improve the efficiency and cost of energy systems. We may reach the point when we may no longer rely mostly on fossil fuel energy.

CASE STUDY 5

Oil-related disasters

The Deepwater Horizon oil spill, also known as the Gulf of Mexico oil spill or the BP oil spill, is considered amongst the largest oil spills in history. On 10 April 2010, an oil well blowout occurred about 5,000 feet below the ocean surface causing a catastrophic explosion on the Deepwater Horizon offshore oil drilling platform. Hundreds of millions of litres of oil have been spilled to date. Work to drill relief wells to permanently close the oil well continues. The best estimate of the spill so far is approximately 12,000 to 19,000 barrels of oil per day. Petroleum toxicity is expected to affect the habitats of thousands of marine and bird species. This ongoing environmental disaster has already impacted the Gulf of Mexico fishing industry and tourism industry.

Hydroelectric power

This uses water flowing down a natural gradient to turn turbines to generate electricity known as 'hydroelectric power' by constructing dams across rivers. Between 1950 and 1970, hydropower generation worldwide increased seven times. The long life of hydropower plants, the renewable nature of the energy source, very low operating and maintenance costs, and absence of inflationary pressures, as in fossil fuels, are some of its advantages.

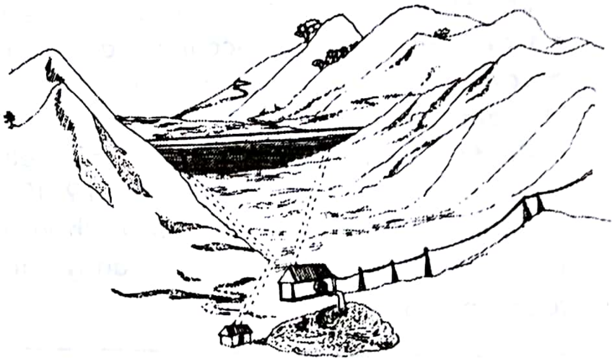
Drawbacks: Although hydroelectric power has led to economic progress around the world, it has created serious ecological problems.

- To produce hydroelectric power, large areas of forest and agricultural lands are submerged. These lands traditionally provided a livelihood for local tribal people and farmers. Conflicts over land use are inevitable.
- The silting of the reservoirs (especially as a result of deforestation) reduces the life of the hydroelectric power installations.

CASE STUDY 6

Hydel power in the Western Ghats

In 1882, the first hydroelectric power dam was built in Appleton, Wisconsin. In India, the first hydroelectric power dams were built in the late 1800s and early 1900s by the Tatas in the Western Ghats of Maharashtra. Jamshedji Tata, a great visionary who developed industry in India in the 1800s, wished to have a clean source of energy to run cotton and textile mills in Bombay as he found people were getting respiratory infections due to coal-driven mills. He therefore asked the British Government to permit him to develop dams in the Western Ghats to generate electricity. The four dams are the Andhra, Shirowata, Valvan and Mulshi hydel dams. An important feature of the Tata power projects is that they use the high rainfall areas in the hills as storage areas. While the rivers flowing eastwards from the Western Ghats are dammed in the foothills near the Deccan Plateau, the water is tunnelled through the crest of the Ghats to drop several hundred metres to the coastal belt. Large turbines in the power plants generate electricity for Mumbai and its giant industrial belt. However, the damming has inundated large forest areas of the Western Ghats. It is important to note that there are several biological and social implications to damming rivers.



- Water is required for many purposes besides power generation. These include domestic, agricultural and industrial requirements. This also gives rise to conflicts over the equitable allocation of water.
- The use of rivers for navigation and fisheries becomes difficult once the water is dammed to generate electricity.
- The resettlement of displaced persons is a problem for which there is no ready solution. The opposition to large hydroelectric schemes is growing, as most dam projects have been unable to resettle or adequately compensate the affected people.
- In certain seismically sensitive regions, large dams can induce increased seismic activity, resulting in earthquakes and the consequent loss of lives and property. There is a great possibility of this occurring around the Tehri Dam in the Himalayan foothills. Shri Sunderlal Bahuguna, the initiator of the Chipko Movement, has fought against the Tehri Dam for several years.

With large dams causing so many social problems, an attempt has made to develop small hydroelectric generation units. Multiple small dams have less impact on the environment. China has the largest number of these—60,000, generating 13,250 megawatts, that is 30% of China's electricity. Sweden, the US, Italy and France have also developed small dams for electrical power generation. The development of small hydroelectric power units could become a very important resource in India, which has rivers traversing steep gradients as well as the economic capability and technical resources to exploit them.

Solar energy: In one hour, the sun pours as much energy onto the earth as we use in a whole year. If it were possible to harness this colossal quantum of energy, humanity would need no other source. Today, we have developed several methods of collecting this energy for heating water and generating electricity.

Solar heating for homes: Modern houses that use air conditioning and/or heating are extremely energy dependent. A passive solar home or building is designed to collect the sun's heat through large, south-facing glass windows. In solar-heated buildings, *sunspaces* are built on the south side of the structure and act as large heat absorbers. The floors of sunspaces are usually made of tiles or bricks that absorb heat throughout the day and then release heat at night when it is cooler.

In energy-efficient architecture, the sun, water and wind are used to heat a building when the weather is cold and to cool it in summer. This is mostly based on design and building material. Thick walls of stone or mud were used in traditional architecture as insulators. Small doors and windows kept direct sunlight and heat out. Deeply-set glass windows in colonial homes, on which direct sunlight could not reach, permitted the use of glass without creating a greenhouse effect; verandahs also served a similar purpose. Traditional bungalows also had high roofs and ventilators that permitted the hot air to rise and leave the room. Cross-ventilation where wind can drive the air in and out of a room keeps it cool. Large overhangs or eaves over windows prevent the glass from heating the room inside. Double walls are used to prevent heating, and shady trees around the house help reduce the temperature.

Solar water heating: Most solar water-heating systems have two main parts—the solar 'collector' and the 'storage tank'. The solar energy collector heats the water, which then flows to a well-insulated storage tank. A common type of collector is the 'flat-plate collector', a rectangular box with a transparent cover that faces the sun, usually mounted on a flat roof. Small tubes run through the box, carrying the water or any other fluid such as antifreeze, to be heated. The tubes are mounted on a metal 'absorber plate', which is painted black to absorb the sun's heat. The back and sides of the box are insulated to hold in the heat. Heat builds up in the collector and as the fluid passes through the tubes, it too heats up.

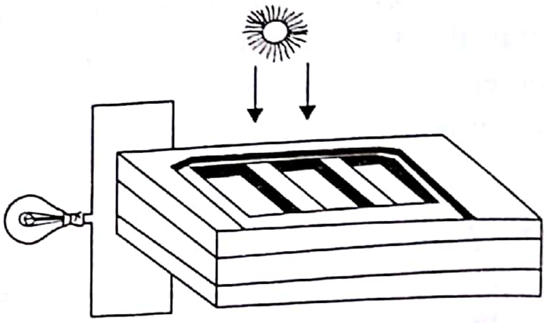
Solar water-heating systems cannot heat water when the sun is not shining. Thus, homes must also have a conventional backup system. About 80% of homes in Israel have solar water heaters.

Solar cookers: The heat produced by the sun can be harnessed directly for cooking using solar cookers. A solar cooker is a metal box, which is black on the inside to absorb and retain heat. The lid has a reflective surface to reflect the heat from the sun into the box. The box contains black vessels in which the food to be cooked is placed.

India has the world's largest solar cooker programme and an estimated 2 lakh families that use solar cookers. Although solar cookers reduce the need for fuelwood and pollution from smoky wood fires, they have not yet become popular in rural areas as it is felt that they are not suitable for traditional cooking practices. However, they have great potential if marketed well.

Other solar-powered devices: Solar desalination systems (for converting saline or brackish water into pure distilled water) have been developed. In future, they should become important alternatives for our future economic growth in areas where freshwater is not available.

Photovoltaic energy: The solar technology that has the greatest potential for use throughout the world is that of solar photovoltaic cells, which directly produce electricity from sunlight using photovoltaic (PV) (also called solar cells or solar panels). PV cells use the sun's light,



not its heat, to make electricity. PV cells require little maintenance, have no moving parts and essentially no environmental impact. They work cleanly, safely and silently. They can be installed quickly in small modules, in any place where there is sunlight. Solar cells are made up of two separate layers of silicon, each of which contains an electric charge. When light hits the cells, the charges begin to move between the two layers and electricity is produced. PV cells are wired together to form a module. A module of about 40 cells is enough to power a light bulb. For more power, PV modules are wired together into an array. PV arrays can produce enough power to meet the electrical needs of a home. Over the past few years, extensive work has been done in decreasing PV technology costs, increasing efficiency and extending cell lifetimes. Many new materials, such as amorphous silicon, are being tested to reduce costs and automate manufacturing.

PV cells are commonly used today in calculators and watches. They also provide power to satellites, electric lights, small electrical appliances such as radios, for water pumping, highway lighting, weather stations and other electrical systems located away from power lines. Some electric utility companies are building PV systems into their power supply networks.

PV cells are environmentally benign; that is, they do not release pollutants or toxic material into the air or water, there is no radioactive substance and no possible catastrophic accidents. Some PV cells, however, do contain small quantities of toxic substances such as cadmium, and these can be released into the environment in the event of a fire. PV cells are made of silicon which, although the second most abundant element in the earth's crust, has to be mined. Mining creates environmental problems. PV systems, of course, only work when the sun is shining and thus need batteries to store the electricity.

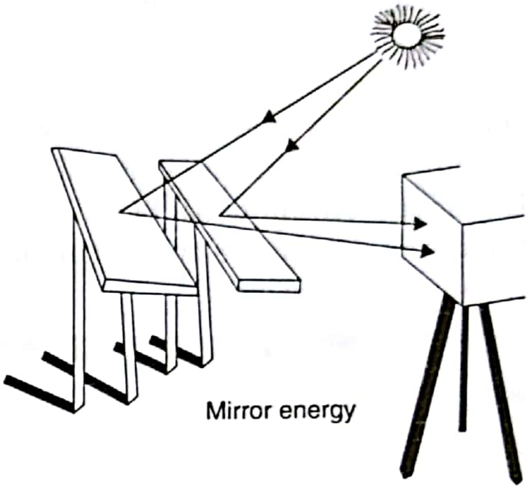
CASE STUDY 7

Solar power

- In 1981, a plane called 'The Solar Challenger' flew from Paris to England in 5 hours, 20 minutes. It had 16,000 solar cells glued to its wings and tail, and they produced enough power to drive a small electric motor and propeller. Since 1987, every three years there is a World Solar Challenge for solar-operated vehicles in Australia, where the vehicles cover 3000 km!
- The world's first solar-powered hospital is in Mali in Africa. Situated at the edge of the Sahara desert, Mali receives a large amount of sunlight. Panels of solar cells supply the power needed to run vital equipment and keep medical supplies cool in refrigerators.
- Space technology requires solar energy and the space race spurred the development of solar cells. Only sunlight can provide power for long periods of time for a space station or long-distance spaceship.
- Japanese farmers are substituting PV-operated insect killers for toxic pesticides.
- In recent years, the popularity of Building Integrated Photovoltaics (BIPVs) has grown considerably. In this application, PV devices are designed as part of the building materials (that is, roofs and siding) both to produce electricity and reduce costs by replacing the costs of normal construction materials. There are more than 3,000 BIPV systems in Germany and Japan has a programme that will build 70,000 BIPV buildings.

Solar thermal electric power (STE): Solar radiation can produce high temperatures, which can generate electricity. Areas with low cloud cover with little scattered radiation, as in the desert, are considered the most suitable sites. According to a UNDP assessment, STE is about 20 years behind the wind energy market exploitation, but is expected to grow rapidly in the near future.

Mirror energy: During the 1980s, a major solar thermal electrical generation unit was built in California, containing 700 parabolic mirrors, each with 24 reflectors, 1.5 m in diameter, which focussed the sun's energy to produce steam to generate electricity.


Mirror energy

Biomass energy: When a log of wood is burned, we are using biomass energy. Because plants and trees depend on sunlight to grow, biomass energy is a form of stored solar energy. Although wood is the largest source of biomass energy, we also use agricultural waste, sugarcane waste and other farm byproducts to make energy.

There are three ways to use biomass. It can be burned to produce heat and electricity, changed to a gas-like fuel such as methane or changed to a liquid fuel. Liquid fuels, also called *biofuels,* include two forms of alcohol—*ethanol* and *methanol.* Because biomass can be changed directly into liquid fuel, it could someday supply much of our transportation fuel needs for cars, trucks, buses, airplanes and trains with diesel fuel replaced by *biodiesel* made from vegetable oils. In the US, this fuel is now being produced from soybean oil. Researchers are also developing algae that produce oils, which can be converted to biodiesel, and new ways have been found to produce ethanol from grasses, trees, bark, sawdust, paper and farming wastes.

Organic municipal solid waste includes paper, food waste and other organic non–fossil fuel-derived materials such as textiles, natural rubber and leather, that are found in the waste of urban areas. Currently, in the US, approximately 31% of organic waste is recovered from municipal solid waste via recycling and composting programmes, 62% is deposited in landfills and 7% is incinerated. Waste material can be converted into electricity by combustion boilers or steam turbines.

Note that like any fuel, biomass creates some pollutants, including carbon dioxide, when burned or converted into energy. In terms of air pollutants, biomass generates less in comparison to fossil fuels. Biomass is naturally low in sulphur and therefore, when burned, generates low sulphur dioxide emissions. However, if burned in the open air, some biomass feedstock would emit relatively high levels of nitrous oxides (given the high nitrogen content of plant material), carbon monoxide, and particulates.

Biogas: Biogas is produced from plant material, animal waste, garbage, waste from households and some types of industrial waste such as fish processing, dairies and sewage treatment plants. It is a mixture of gases which includes methane, carbon dioxide, hydrogen sulphide and water vapour. In this mixture, methane burns easily. From 1 ton of food waste, one can produce 85 cu m of biogas. Once used, the residue is used as an agricultural fertiliser.

Denmark produces a large quantity of biogas from waste and 15,000 mW of electricity from 15 farmers' cooperatives. London has a plant which makes 30 mW of electricity a year from

420,000 t of municipal waste, which supplies power to 50,000 families. In Germany, 25% of landfills for garbage produce power from biogas; Japan uses 85% of its waste in a similar way and France about 50%.

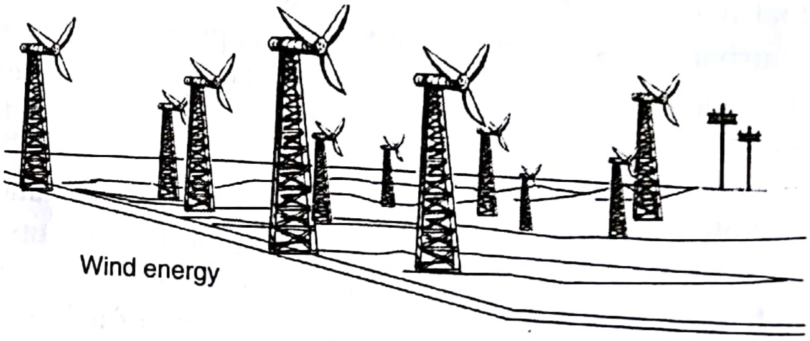
Biogas plants have become increasingly popular in India in the rural sector. The biogas plants use cowdung that is converted into a gas which is used as a fuel. It is also used for running dual fuel engines. The reduction in kitchen smoke by using biogas has reduced lung problems in thousands of homes.

The fibrous waste of the sugar industry is the world's largest potential source of biomass energy. Ethanol produced from sugarcane molasses is a good automobile fuel and is now used in a third of the vehicles in Brazil. The National Project on Biogas Development (NPBD) and Community/Institutional Biogas Plant Programme promote various biogas projects. In 1996, there were already 2.18 million families in India that used biogas. However, China has 20 million households using biogas!

Let's do it!

What you throw out in your garbage today could be used as fuel for someone else. Municipal solid waste has the potential to be a large energy source. Garbage is an inexpensive energy resource. Unlike most other energy resources, someone will collect garbage, deliver it to the power plant and even pay to get rid of it. This helps cover the cost of turning garbage into energy. Garbage is also a unique resource because we all contribute to it.

Keep a record of all the garbage that you and our family produce in a day. What proportion of it is in the form of biomass? Weigh this. How long would it take you to gather enough waste biomass to make a tank-full (0.85 cu m) of biogas? (Remember 1 t of biomass produces 85 cu m of biogas.)


Wind energy

Wind power: Wind was the earliest energy source used for transportation by sailing ships. About 2000 years ago, windmills were developed in China, Afghanistan and Persia to draw water for irrigation and to grind grain. Most of the early work on generating electricity from wind was carried out in Denmark at the end of the last century. Today, Denmark and California have large wind turbine cooperatives, which sell electricity to the government grid. In Tamil Nadu, there are large wind farms producing 850 mW of electricity. At present, India is the third-largest producer of wind energy in the world.

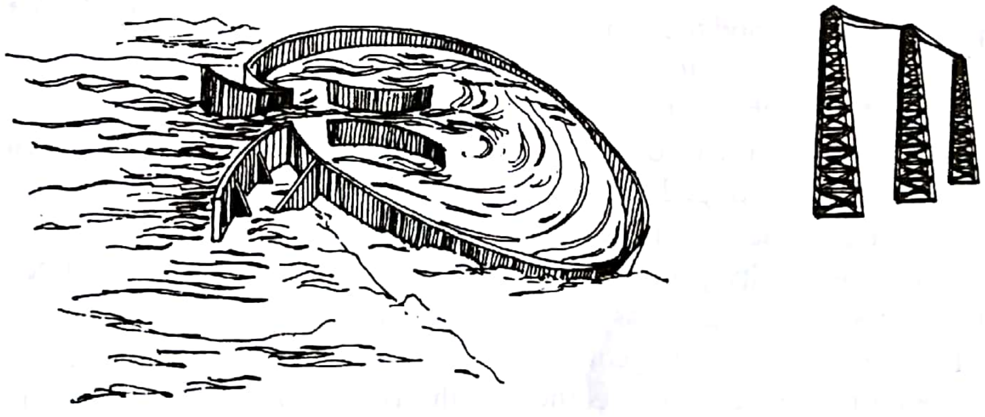
Wind power is a function of the wind speed and therefore, the average wind speed of an area is an important determinant of economically feasible power. Wind speed increases with height. At a given turbine site, the power available 30 m above ground is typically 60% greater than at 10 m. Over the past two decades, a great deal of technical progress has been made in the design, siting, installation, operation and maintenance of power-producing windmills (turbines). These improvements have led to higher wind conversion efficiency and lower electricity production costs.

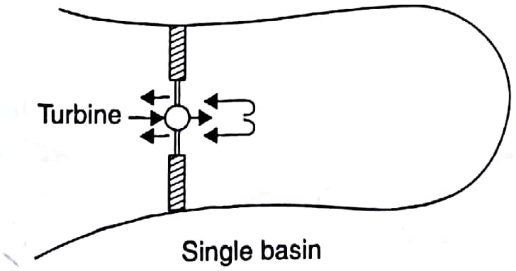
Environmental impact: Wind power has little environmental impact, as there are virtually no air or water emissions, radiation or solid waste production. The principal problems are bird kills, noise, effect on TV reception and aesthetic objections to the sheer number of wind turbines that are required to meet electricity needs. Although large areas of land are required for setting up wind farms, the amount used by the turbine bases, the foundations and the access roads is less than 1% of the total area covered by the wind farm. The rest of the area can also be used for agricultural purposes or for grazing. Siting windmills offshore reduces their demand for land and visual impact.

Wind is an intermittent source and the intermittency of wind depends on the geographic distribution of wind. Wind, therefore, cannot be used as the sole resource for electricity and requires some other backup or standby electricity source.

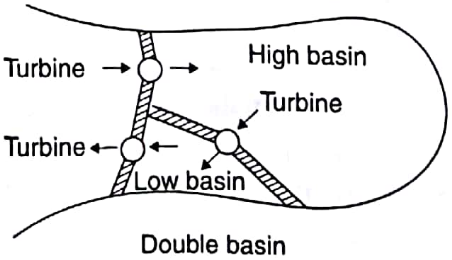
Tidal and wave power: The energy of waves in the sea that crash on the land of all the continents is estimated at 2–3 million mW of energy. From the 1970s onwards, several countries have been experimenting with technology to harness the kinetic energy of the ocean to generate electricity. Tidal power is tapped by placing a barrage across an estuary and forcing the tidal flow to pass through turbines. In a one-way system, the incoming tide is allowed to fill the basin through a sluice, and the water so collected is used to produce electricity during low tide. In a two-way system, power is generated from both incoming as well as outgoing tides.

Wave power plant





Single basin



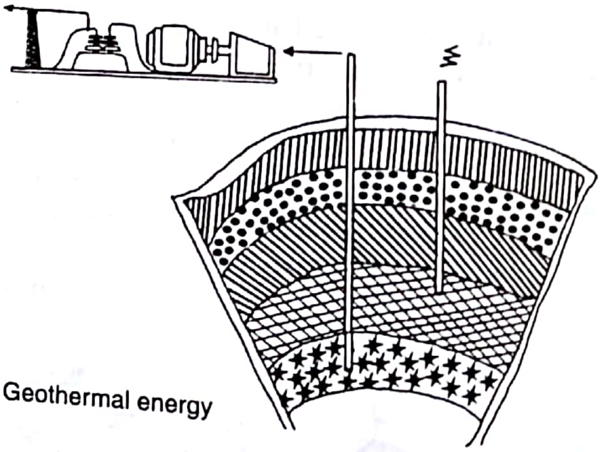
Double basin

However, tidal power stations bring about major ecological changes in the sensitive ecosystem of coastal regions and can destroy the habitats and nesting places of water birds and interfere with fisheries. A tidal power station at the mouth of a river blocks the flow of polluted water into the sea, thereby creating health and pollution hazards in the estuary. Other drawbacks include offshore energy devices posing navigational hazards. The residual drift current could affect the spawning of some fish, whose larvae would be carried away from the spawning grounds. They may also affect the migratory patterns of surface swimming fish.

Wave power converts the motion of waves into electrical or mechanical energy. For this, an energy extraction device is used to drive turbo-generators. Electricity can be generated at sea and transmitted by cable to land. This energy source has yet to be fully explored. The largest concentration of potential wave energy on earth is located between 40 and 60 degrees latitude in both the northern and southern hemispheres, where the winds blow most strongly.

Another developing concept that harnesses energy due to the differences in temperature between the warm upper layers of the ocean and the cold deep-sea water is called Ocean Thermal Energy Conversion (OTEC). This is a high-tech installation, which may prove to be highly valuable in the future. At present, the Department of Ocean Development (DOD) has one plant in Tiruchendur in Tamil Nadu, producing 1 mW a day.

Geothermal energy: This is the energy stored within the earth ('geo' for earth and 'thermal' for heat). Geothermal energy starts with hot, molten rock (called *magma*) deep inside the earth, which surfaces at some parts of the earth's crust. The heat rising from the magma warms underground pools of water known as *geothermal reservoirs*. If there is an opening, hot underground water comes to the surface and forms hot springs or it may boil to form geysers. With modern technology, wells are drilled deep below the surface of the earth to tap into geothermal reservoirs. This is called 'direct' use of geothermal energy, and it provides a steady stream of hot water that is pumped to the earth's surface.



Geothermal energy

In the 20th century, geothermal energy has been harnessed on a large scale for space-heating, industrial use and electricity production, especially in Iceland, Japan and New Zealand. Geothermal energy is nearly as cheap as hydropower; there are, however, very few good examples of this. Furthermore, water from geothermal reservoirs often contains minerals that are corrosive and polluting. In addition, geothermal fluids contain contaminants which must be treated before disposal.

Nuclear power

In 1938 two German scientists, Otto Hahn and Fritz Strassman, demonstrated nuclear fission. They found they could split the nucleus of a uranium atom by bombarding it with neutrons. As the nucleus split, some mass was converted to energy. The nuclear power industry, however, was born in the late 1950s. The first large-scale nuclear power plant in the world became operational in 1957, in Pennsylvania, USA.

As of 2008, India and the US have an agreement facilitating nuclear cooperation in energy and satellite technology between the two countries. The US's three-decade suspension of nuclear trade with India has been lifted.

Homi Bhabha is considered the father of nuclear power development in India. The Bhabha Atomic Research Centre (BARC) in Mumbai studies and develops modern nuclear technology. India has ten nuclear reactors at five nuclear power stations that produce 2% of India's electricity. These are located in Maharashtra (Tarapur), Rajasthan, Tamil Nadu, Uttar Pradesh and Gujarat. India has uranium from mines in Bihar. There are also thorium deposits in Kerala and Tamil Nadu.

The nuclear reactors use uranium-235 to produce electricity. The energy released from 1 kg of uranium-235 is equivalent to that produced by burning 3,000 t of coal. U-235 is made into rods that are fitted into a nuclear reactor. The control rods absorb neutrons and thus adjust the fission, which releases energy due to the chain reaction in a reactor unit. The heat energy produced in the reaction is used to heat water and produce steam, which drives turbines that produce electricity. The drawback is that the rods need to be changed periodically. This has an adverse impact on the environment due to the disposal of nuclear waste. Additionally, the reaction releases very hot waste water that potentially damages aquatic ecosystems, even though it is cooled by a water system before it is released.

The cost of nuclear power generation must include the high cost of disposal of its waste and the decommissioning of old plants. These have high economic as well as ecological costs that are not taken into account when developing new nuclear installations. For environmental reasons, Sweden has decided to become a nuclear-free country by 2010.

Although the conventional environmental impact from nuclear power is negligible, what overshadows all the other types of energy sources is that an accident can be devastating and the effects last for long periods of time. While it does not pollute air or water routinely like oil or biomass, a single accident can kill thousands of people, make many others seriously ill, and destroy an area for decades by its radioactivity which leads to death, cancer and genetic deformities. Land, water, vegetation are destroyed for long periods of time. The management, storage and disposal of radioactive waste resulting from nuclear power generation are the biggest expenses of the nuclear power industry. There have been horrifying nuclear accidents at Chernobyl in USSR and at the Three-Mile Island in the USA. The radioactivity unleashed by such accidents can affect humans for generations.

Energy conservation

Conventional energy sources affect nature and human society in different ways. India needs to rapidly move towards a policy to reduce energy needs and use cleaner energy production technologies. Here are some approaches towards energy conservation in India:

- A shift to alternative energy use and renewable energy sources that are used judiciously and equitably would bring about environmentally friendly and sustainable lifestyles. This would also reduce India's dependency on imported oil.
- Electricity losses in India during transmission and distribution are significantly high—approximately 30–45%. And this is before we even turn on our bulbs at home! Minimising these losses is critical to effective energy conservation in India.
- Small hydrogeneration units are environment-friendly. They do not displace people, destroy forests or wildlife habitats or kill aquatic and terrestrial biodiversity. They can be placed on several hill-streams, canals or rivers. The generation depends on flowing water due to gravity. However, this fails if the flow is seasonal. An estimated potential of about 15,000 MW of small hydrogeneration projects exist in India. Andhra Pradesh, Arunachal Pradesh and Assam are examples of some states where small hydro projects have been implemented.

- Enhancing fuelwood plantations and managing them through JFM.
- Using energy-efficient cooking stoves or *chulhas* which help the movement of air through them, making the wood burn more efficiently. Additionally, these stoves have a chimney to minimise air pollution and thus reduce respiratory problems.
- Biomass generated from firewood, cattle dung, crop residue such as rice husk, coconut shells or straw can be converted into biogas or liquid fuels; that is, ethanol and methanol. This can provide a low-cost fuel option for heating purposes such as cooking. Alternatively, biogas can be compressed and used to power motor vehicles.
- Unplanned and inefficient public transport systems, especially in cities, also waste a large amount of energy. Providing for bicycle paths during the town planning stage would encourage more people to conserve energy by using bicycles.
- In the agricultural sector, irrigation pumps to lift water are the most energy intensive; these are either electrical or run on fossil fuels. Alternative energy sources such as solar-powered irrigation pumps should be used instead.
- Large-energy consumers include chemical industries, especially petrochemical units, iron and steel, textiles and paper. Efforts must be made by these industries to be more energy efficient.

DELHI

It is easy to waste energy but cheaper to save it than generate it. We can conserve energy by preventing or reducing energy waste and by using resources more efficiently. People often waste energy because the government subsidises it. If the real cost was levied, people would not be able to afford to waste it carelessly.

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(vi) Land Resources

Land as a resource: Landforms like hills, valleys, plains, river basins and wetlands include different resource-generating areas that the people living in them depend on. Many traditional farming societies had ways of preserving areas from which they used resources. For example, in the 'sacred groves' of the Western Ghats, requests to the spirit of the grove for permission to cut a tree or extract a resource were accompanied by simple rituals. The outcome of a chance fall on one side or the other of a stone balanced on a rock gave or withheld permission. The request could not be repeated for a specified period.

If land is utilised carefully, it can be considered a renewable resource. The roots of trees and grasses bind the soil. If forests are depleted or grasslands overgrazed, the land becomes unproductive and wasteland is formed. Intensive irrigation leads to water-logged and salinised soil, on which crops cannot grow. Land is also converted into a non-renewable resource when highly toxic industrial and nuclear waste is dumped on it.

Land on earth is as finite as any other natural resource. While humans have learnt to adapt our lifestyle to various ecosystems, we cannot live comfortably for instance on polar ice caps, under the sea or in space in the foreseeable future. We need land for building homes, cultivating food, maintaining pastures for domestic animals, developing industries to provide goods and supporting the industries by creating towns and cities. Equally importantly, humans need to protect wilderness areas in forests, grasslands, wetlands, mountains and coasts to protect our critically valuable biodiversity.

Thus, the rational use of land demands careful planning. One can develop most of these different types of land uses almost anywhere, but protected areas (national parks and wildlife sanctuaries) can only be situated where some of the natural ecosystems are still undisturbed. These PAs are important aspects of good land use planning.

Land degradation: Farmland is under threat due to more and more intense utilisation. Every year, between 5–7 mha of land worldwide is added to the existing degraded farmland. When soil is used more intensively for farming, it is eroded even more rapidly by wind and rain. Over-irrigating farmland leads to salinisation as the evaporation of water brings the salts to the surface of the soil on which crops cannot grow. Over-irrigation also creates water-logging of the topsoil, so that crop roots are affected and the crop deteriorates. The use of more and more chemical fertilisers poisons the soil and eventually the land becomes unproductive.

As urban centres grow and industrial expansion occurs, the agricultural land and forests shrink. This is a serious loss and will have unfavourable long-term effects on human civilisations.

Soil erosion: The characteristics of natural ecosystems, such as forests and grasslands, depend on the type of soil. Soil of various types supports a wide variety of crops. The misuse of an ecosystem leads to the loss of valuable soil through erosion by the monsoon rains and, to a smaller extent, by wind. The roots of the trees in the forest hold the soil. Deforestation thus leads to rapid soil erosion. Soil is washed away into streams, transported into rivers and finally lost to the sea. The process is more evident in areas where deforestation has led to erosion on steep hill-slopes as in the Himalayas and in the Western Ghats. These areas are called 'ecologically sensitive areas' or ESAs. To prevent the loss of millions of tons of valuable soil every year, it is essential to preserve what remains of our natural forest cover. It is equally important to reforest denuded areas. The link between the existence of forests and the presence of soil is greater than the forest's physical soil binding function alone. The soil is enriched by the leaf-litter of the forest. This detritus is broken down by soil microorganisms, fungi, worms and insects, which help to recycle nutrients in the system. Further loss of our soil wealth will impoverish the country and reduce its capacity to grow enough food in the future.

LIBRARY

2.3 ROLE OF AN INDIVIDUAL IN THE CONSERVATION OF NATURAL RESOURCES

Until fairly recently, humans acted as if we could endlessly exploit the earth's ecosystems and natural resources like soil, water, forests and grasslands and extract minerals and fossil fuels. However, in the last few decades, it has become increasingly evident that the global ecosystem has the capacity to sustain only a limited level of utilisation. Biological systems cannot go on replenishing resources if they are overused or misused. At a critical point, increasing pressure destabilises their natural balance. Even biological resources traditionally classified as 'renewable' – such as those from our oceans, forests, grasslands and wetlands – are being degraded by overuse and may be permanently destroyed. And no natural resource is limitless. Non-renewable resources will be rapidly exhausted if we continue to use them as intensively as at present.

The two most damaging factors leading to the current rapid depletion of all forms of natural resources are increasing consumerism on the part of the affluent sections of society and rapid population growth. Both factors are the result of choices *we make as individuals.* As individuals we need to decide;

- What will we leave to our children? (Are we thinking of short-term or long-term gain?)
- Is my material gain someone else's loss?

In general, acquisitiveness has become a way of life for the majority of people in the developed world. Population growth and the resulting shortage of resources most severely affect people in the developing countries. In nations such as ours, which are both developing rapidly and suffering from a population explosion, both factors are responsible for environmental degradation. We must ask ourselves if we have perhaps reached a critical flashpoint, at which economic 'development' affects the lives of people more adversely than the benefits it provides.

Let's do it!

- Turn off lights and fans as soon as you leave the room.
- Use tubelights and energy efficient bulbs such as CFLs and LEDs that save energy rather than incandescent bulbs. A 40 W tubelight gives as much light as a 100 W incandescent bulb, a 25 W CFL gives as much light for the same incandescent bulb, and finally depending on the level of illumination chosen, a 3 W LED is equivalent in output to a 45 W incandescent bulb.
- Keep the bulbs and tubes clean. Dust on tubes and bulbs decreases lighting levels by 20%–30%.
- Switch off the television or radio as soon as the program of interest is over.
- A pressure cooker can save up to 75% of the energy required for cooking. It is also faster.
- Keeping the vessel covered with a lid during cooking helps to cook food faster, thus saving energy.

CASE STUDY 8

Incentive to conserve

Pune's energy model is a unique Public–Private partnership pattern wherein citizens and the industry work together with Government agencies to conserve energy. All consumers whose monthly energy consumption is less than 300 units a month, do not need to pay 'reliability charges' levied to recover the incremental costs of getting extra power at a higher cost. So small and marginal consumers get the benefit of 24 × 7 electricity without paying a premium price. This further promotes energy conservation as consumers have the incentive to bring down their monthly consumption below 300 units, in order to save themselves the extra charge.

2.4 EQUITABLE USE OF RESOURCES FOR SUSTAINABLE LIFESTYLES

Reducing the unsustainable and unequal use of resources and controlling our population growth are essential for the survival of our nation and indeed, of humans everywhere. Our environment provides a variety of goods and services necessary for day-to-day life, but the soil, water, climate and solar energy, which form the abiotic support that we derive from nature, are not distributed evenly throughout the world or within countries. A new economic order at the global and at national levels must be based on the ability to distribute benefits of natural resources by sharing them more equally among the countries as well as among communities within countries such as our own. It is at the local level where people subsist by the sale of locally collected resources, that the disparity is greatest. Development has not reached them and they are often unjustly accused of exploiting natural resources. They must be adequately compensated for the removal of the sources to distant regions and thus develop a greater stake in protecting natural resources.

There are several principles that each of us can adopt to bring about sustainable lifestyles. This primarily comes from caring for the earth in all respects. A love and respect for nature is the greatest sentiment that helps bring about a feeling for looking at how we use natural resources in a new and sensitive way. Think of the beauty of wilderness, a natural forest in all its magnificence, the expanse of a green grassland, the clean water of a lake that supports so much life, the crystal-clear water of a hill-stream, or the magnificent power of the oceans, and we cannot help but support the conservation of nature's wealth. If we respect this, we cannot commit acts that will deplete our life-supporting systems.

Summary

- A renewable resource is a natural resource which, if harvested sustainably, can be regenerated after its use.
- A non-renewable resource is a natural resource that takes millions of years to regenerate and is therefore irreplaceable after consumption.
- Pressures of an increasing population, changes in land use, over-consumption and pollution are some of the major threats to our fast depleting natural resources.
- Conservation and natural resource use efficiency along with an equitable distribution of natural resources is the key to a sustainable lifestyle.

Questions

1. Write about any two natural renewable resources and describe two problems associated with each of them.
2. What is a non-renewable resource? Give two examples of non-renewable resources.
3. Provide three examples of renewable energy sources. Provide two advantages and two disadvantages for each.
4. In terms of resource use, what are some of the steps we can take to lead a more sustainable lifestyle?

Unit 3

Ecosystems

Let's understand

- What an ecosystem is
- How to utilise the existing resources
- The structure and functions of an ecosystem
- What producers, consumers and decomposers are
- How energy flows in the ecosystem
- How the various cycles—water, carbon, oxygen, nitrogen, phosphorus, sulphur, energy—operate in nature
- What ecological succession is
- What food chains, food webs and ecological pyramids are
- The various types of ecosystems
- The characteristic features, structure and functions of various ecosystems
- Why degradation of ecosystems takes place

3.1 CONCEPT OF AN ECOSYSTEM

An 'ecosystem' is a region with a specific and recognisable landscape form, such as a forest, grassland, desert, wetland or coastal area. The nature of the ecosystem depends on its geographical features such as hills, mountains, plains, rivers, lakes, coastal areas or islands and is also controlled by climatic conditions—the amount of sunlight, temperature and rainfall in the region. The geographical, climatic and soil characteristics form its non-living or **abiotic components.** These features create conditions that support a community of plants and animals that evolution has produced to live in these specific conditions. The living part of the ecosystem is referred to as the **biotic component.**

Ecosystems are divided into terrestrial or land-based ecosystems and aquatic or water-based ecosystems. These form the two main habitat conditions for the earth's living organisms.

All the living organisms in an area live in communities of plants and animals. They interact with the abiotic environment and with each other at different points in time for a large number of reasons. Life can exist only in a small portion of the earth's land, water and atmosphere. At a global level, the thin skin of the earth on the land, sea and air forms the biosphere.

At a sub-global level, this is divided into *biogeographical realms*. For example, Eurasia is called the Palearctic realm; South and Southeast Asia (of which India forms a major part) is the Oriental realm; North America is the Nearctic realm; South America forms the Neotropical realm; Africa the Ethiopian realm; and Australia the Australian realm.

At a national or state level are *biogeographic regions*. India has several distinctive geographical regions—the Himalayas, the Gangetic plains, the highlands of Central India, the Western and Eastern ghats, the semi-arid desert in the West, the Deccan plateau, the coastal belts and the Andaman and Nicobar Islands. These geographically distinctive areas contain plants and animals that have adapted themselves to live in each of these regions. At an even more local level, each area has several structurally and functionally identifiable *ecosystems*, such as different types of forests, grasslands, river catchments, mangrove swamps in deltas, seashores or islands to give just a few examples. Here, too, each of these forms a habitat for specific plants and animals.

Definition: The living community of plants and animals in any area together with the non-living components of the environment—soil, air and water—constitute the ecosystem.

3.1.1 Understanding Ecosystems

Natural ecosystems include forests, grasslands, deserts and aquatic ecosystems such as ponds, rivers, lakes and the sea. Human-modified ecosystems include agricultural land and urban or industrial land use patterns.

Each ecosystem has a set of common features that can be observed in the field:

- What does the ecosystem look like?
  One should be able to describe specific features of the different ecosystems in one's own surroundings. Field observations must be made in both urban and natural surroundings.
- What is its structure?
  Is it a forest, a grassland, a water body, an agricultural area, a grazing area, an urban area or an industrial area?
  What you should look for are its different characteristics. A forest has various layers from the ground to the canopy. A pond has different types of vegetation from the periphery to its centre. The vegetation on a mountain changes from its base to its summit.
- What is the composition of its plant and animal species?
  List the well-known plants and animals you can see. Then, document their abundance and numbers in nature—very common, common, uncommon, rare. For example, wild mammals will not be seen in large numbers, cattle would be common. Some birds are common; find out which are the most common species. Insect species are very common and most abundant. In fact, there are so many that they cannot be easily counted.
- How does the ecosystem work?
  The ecosystem functions through several biogeochemical cycles and energy-transfer mechanisms. Observe and document the components of the ecosystem, which consist of its non-living or abiotic features such as air, water, climate and soil and its biotic components, the various plants and animals. Both these aspects of the ecosystem interact with each other through several functional aspects to form nature's ecosystems. Plants, herbivores and carnivores can be seen to form food chains. All these chains are joined together to form

a 'web of life' on which man depends. Each of these food chains uses energy that comes from the sun and powers the ecosystem.

3.1.2 Resource Utilisation

Most traditional societies used their environmental resources fairly sustainably. Though inequality in resource utilisation has existed in every society, the number of individuals that used a large proportion of resources was extremely limited. In recent times, the proportion of rich people in affluent societies has grown rapidly. Inequality has thus become a serious challenge. Whereas in the past many resources such as timber and fuelwood from the forest were extracted sustainably, this pattern has drastically changed during the last century. The economically powerful sections began to use greater amounts of forest products, while those people who lived in the forest became increasingly poor. Similarly, the building of large irrigation projects has led to wealth in those areas that had canals, while those who remained dependent on a constant supply of water from the river itself have found it difficult to survive.

The key to this issue is the need for an equitable distribution of all types of natural resources. A more even sharing of resources within the community can reduce these pressures on the natural ecosystems.

3.2 STRUCTURE AND FUNCTIONS OF AN ECOSYSTEM

Since each ecosystem has a non-living and a living part that are linked to each other, one needs to look around and observe this closely.

The non-living components of an ecosystem are the amount of water, inorganic substances and organic compounds, and climatic conditions, which depend on geographical conditions and location. The living organisms in an ecosystem are inseparable from their habitat.

The living component of plant life ranges from extremely small bacteria, which live in the air, water and soil, algae which live in fresh and saltwater, to the terrestrial plants which range from grasses and herbs that grow after the monsoon every year, to the giant long-lived trees of the forest. The plants convert energy from sunlight into organic matter for their growth, thus functioning as **producers** in the ecosystem. The living components of the animal world range from microscopic animals, to small insects and larger animals such as fish, amphibians, reptiles, birds and mammals. Humans are just one of the 1.8 million species of plants and animals that inhabit the earth.

Structural aspects: This refers to all the elements that make up an ecosystem—the individuals and communities of plants and animals as well as the non-living natural resources present in the ecosystem.

(i) Inorganic compounds—C, N, CO_2, H_2O

(ii) Organic compounds—proteins, carbohydrates, lipids, which link the abiotic to biotic aspects

(Continued)

(iii) Climatic regimes—temperature, moisture, light and topography
(iv) Producers—plants
(v) Macro-consumers—Phagotrophs, that is, large animals
(vi) Micro-consumers—Saprotrophs, that is, absorbers like fungi

Functional aspects: This refers to all the services, processes and interactions performed by the organisms in an ecosystem.

- Energy cycles
- Food chains
- Diversity—interlinks between organisms
- Nutrient cycles—biogeochemical cycles
- Evolution

3.3 PRODUCERS, CONSUMERS AND DECOMPOSERS

Every living organism is in some way dependent on other organisms. Plants are food for herbivorous animals, which are in turn food for carnivorous animals. Thus, there are different trophic levels in the ecosystem. Some organisms such as fungi live only on dead material and inorganic matter.

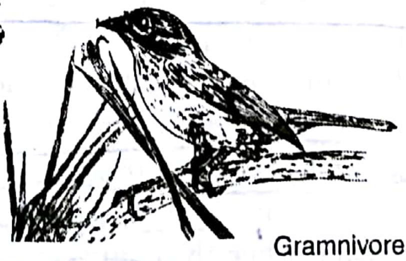
Plants are the *producers* in the ecosystem, as they manufacture their food by using energy from the sun. In the forest, these form communities of plant life. In the sea, these range from tiny algal forms to large seaweed.

The *herbivorous animals* are *primary consumers* as they live on the producers. In a forest, these are the insects, amphibians, reptiles, birds and mammals. The herbivorous animals include, for example, the hare, deer and elephants that live on plant life. They graze on grass or feed on the foliage from trees. In grasslands, there are herbivores such as the blackbuck that feed on grass. In the semi-arid areas, there are animals such as the *chinkara* or Indian gazelle that also feed on grass. In the sea, there are small fish that live on algae and other plants.

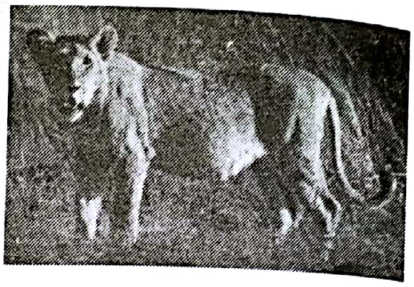
Herbivores

Frugivores

Nectarivores



Gramnivores


ERACH BHARUCHA

Carnivore

At a higher trophic level, there are *carnivorous animals*, or *secondary consumers*, which live on the herbivores. In our forests, the carnivores are tigers, leopards, jackals, foxes and small wild cats. In the sea, carnivorous fish live on other fish and marine animals. The animals that live in the sea range in size from microscopic forms to giant mammals such as the whale.

Decomposers or *detrivores* are a group of organisms consisting of small animals such as worms, insects, bacteria and fungi, which break down dead organic material into smaller particles and finally into simpler substances that are used by plants as nutrition. Thus, decomposition is a vital function in nature, as without this, all the nutrients would be tied up in dead matter and no new life would be produced.

Detrivore

Most ecosystems are highly complex and consist of an extremely large number of individuals of a wide variety of species. In the species-rich tropical ecosystems (such as in India), only a few species are very common, while most species have relatively few individuals. Some species of plants and animals are extremely rare and may occur only at a few locations. These are said to be *endemic* to these areas.

When human activities alter the balance of these ecosystems, such perturbations often lead to the disappearance of some uncommon species. When this happens to an endemic species that is not widely distributed, it becomes extinct forever.

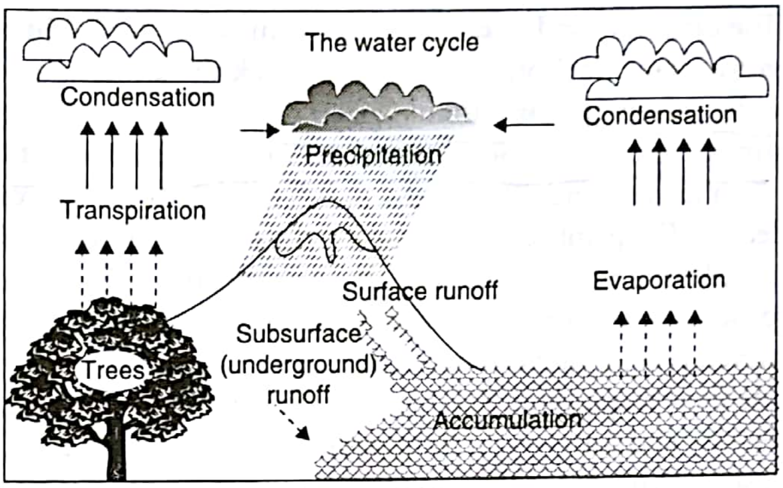
3.4 ENERGY FLOW IN THE ECOSYSTEM

Every ecosystem has several interrelated mechanisms that affect human life. These are the water cycle, carbon cycle, oxygen cycle, nitrogen cycle and energy cycle. While every ecosystem is controlled by these cycles, each ecosystem's abiotic and biotic features are distinct from each other.

All the functions of the ecosystem are in some way related to the growth and regeneration of its plant and animal species. These interlinked processes can be depicted as various cycles; all these processes depend on energy from sunlight. During photosynthesis, carbon dioxide is absorbed by plants and oxygen is released into the atmosphere. Animals depend on this oxygen for their respiration. The water cycle depends on rainfall, which is necessary for plants and animals to live. The energy cycle recycles nutrients into the soil on which plant life grows. Our own lives are closely linked to the proper functioning of these cycles of life. If human activities go on altering them, humanity cannot survive on earth.

3.4.1 The Water Cycle

The hydrologic cycle, also known as the water cycle, collects, purifies and circulates the earth's finite water supply. When it rains, the water runs along the ground and flows into rivers or falls directly into the sea. A part of the rainwater that falls on land percolates into the ground, thus recharging groundwater aquifers. Water is drawn up from the ground by plants along with nutrients from the soil. The water then transpires from the leaves as water vapour and returns to the atmosphere. As it is lighter than air, water vapour rises and forms clouds. The winds blow the clouds for long distances and when the clouds rise higher, the vapour condenses and



changes into droplets, which fall on the land as rain. Part of this rain gets locked in glaciers. Thus, the processes of evaporation from water bodies, transpiration from plant leaves, condensation of water vapour, precipitation and percolation form an endless cycle that replenishes streams, lakes and wetlands. Furthermore, the above mentioned natural processes of the water cycle also remove impurities in water.

While this is an endless cycle on which life depends, human activities are making drastic changes in the water cycle and its processes through over-extraction of surface water and ground water, construction of large dams, deforestation and pollution.

3.4.2 The Carbon Cycle

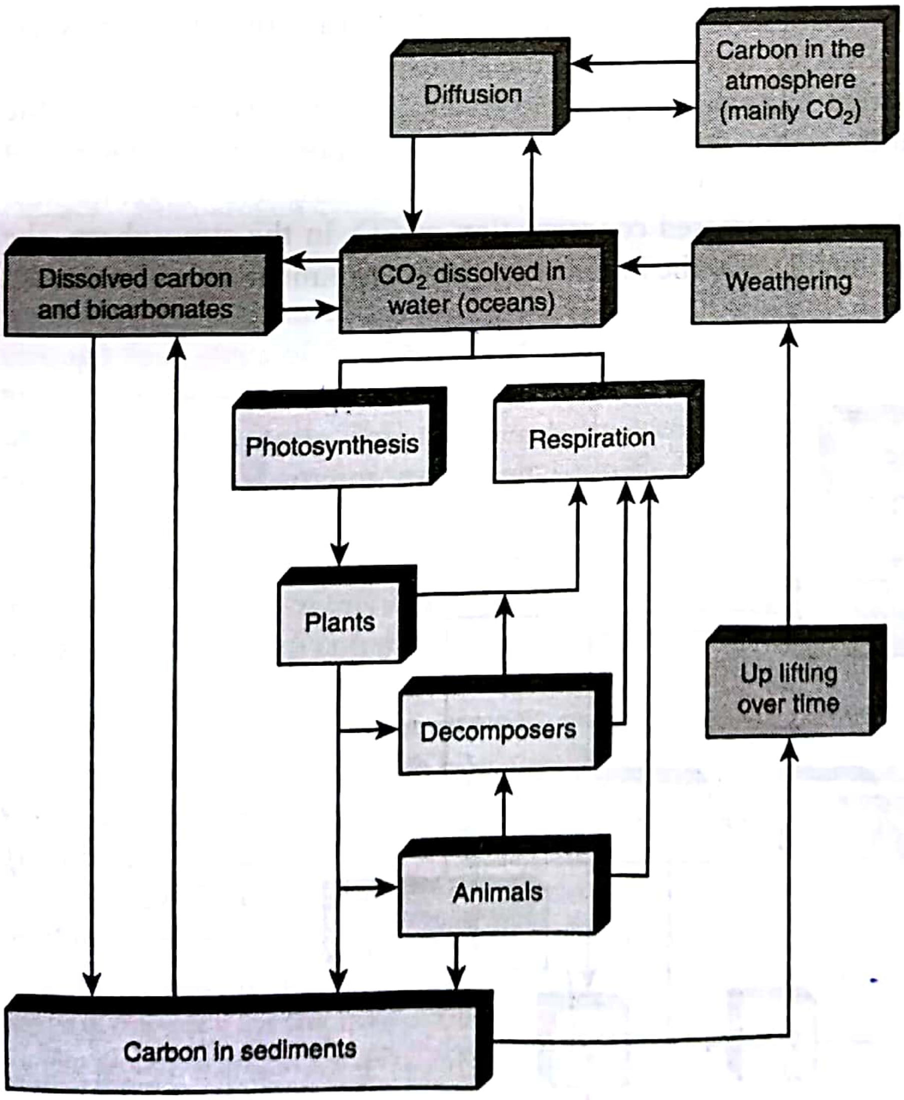

Diffusion
Carbon in the atmosphere (mainly CO_2)
Dissolved carbon and bicarbonates
CO_2 dissolved in water (oceans)
Weathering
Photosynthesis
Respiration
Plants
Decomposers
Up lifting over time
Animals
Carbon in sediments

Fig. 3.1 The carbon cycle

The carbon found in organic compounds is included in both the abiotic and biotic parts of the ecosystem. Carbon is a building block of both plant and animal tissues. The carbon cycle is based on carbon dioxide gas (CO_2). In terrestrial ecosystems, CO_2 is removed from the atmosphere and in aquatic ecosystems, CO_2 is removed from water.

In the presence of sunlight, plants take up carbon dioxide from the atmosphere through their leaves. The plants combine carbon dioxide with water, which is absorbed by their roots from the soil. In the presence of sunlight they are able to form carbohydrates that contain carbon. This process is known as photosynthesis. Plants use this complex mechanism for their growth and development. In this process, plants release oxygen into the atmosphere on which animals depend for their respiration. Furthermore, herbivores feed on plant material, which is used by them for energy and for growth. Both plants and animals release carbon dioxide during respiration. They also return fixed carbon to the soil in the waste they excrete. When plants and animals die, they return their carbon to the soil, thus completing the carbon cycle. Plants play a very important role in regulating and monitoring the percentage of oxygen and carbon dioxide in the earth's atmosphere.

Equally, oceans play a crucial role in the carbon cycle. Some CO_2 is removed by marine species during photosynthesis, some stays dissolved in sea water (making it a major carbon-storage sink), and finally some of the CO_2 reacts with sea water to form carbonate and bicarbonate ions. Cold sea water can hold more carbon than warm sea water, just like cold soft drinks hold their fizz longer than warm soft-drinks. As the temperature of the oceans rise, it becomes less able to absorb CO_2 and thus more CO_2 is released into the atmosphere.

The carbon cycle ensures that CO_2 is at acceptable levels. This in turn moderates the temperature for life to exist. If the carbon cycle removes too much carbon, the atmosphere will become cool and if too much carbon is added to the atmosphere, the atmosphere will get warmer.

Current climate models show an increased concentration of CO_2 in the atmosphere. The resulting climate change phenomenon is at the forefront of the environmental problems faced by the world today.

3.4.3 The Oxygen Cycle

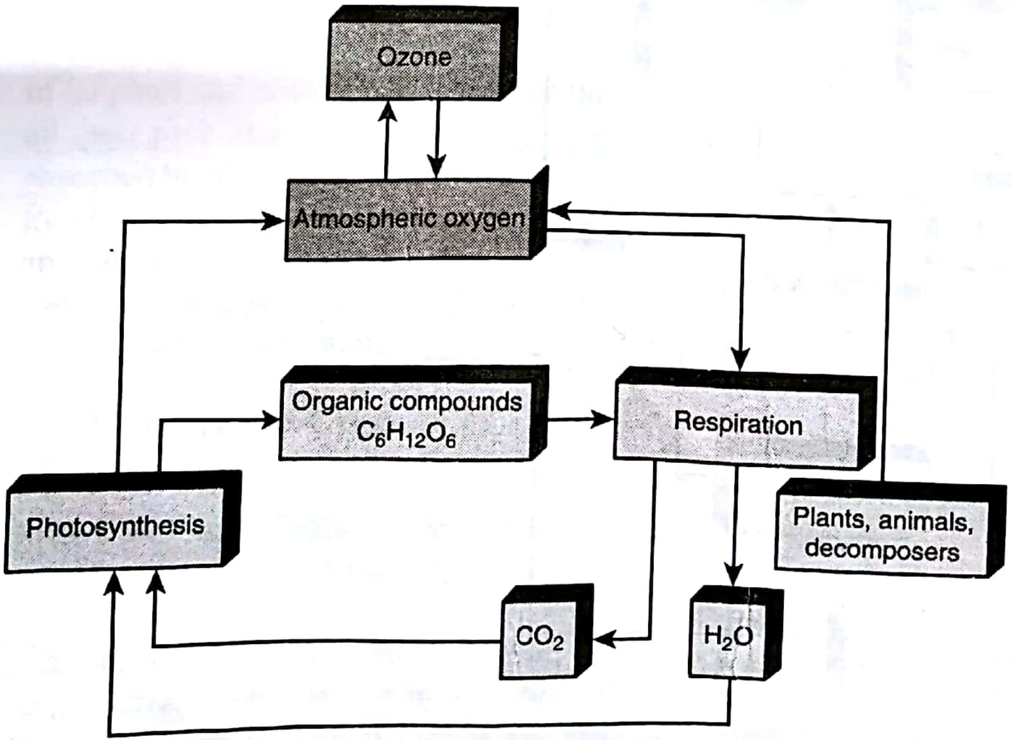

Ozone
Atmospheric oxygen
Organic compounds $C_6H_{12}O_6$
Respiration
Photosynthesis
Plants, animals, decomposers
CO_2
H_2O

Fig. 3.2 The oxygen cycle

Oxygen is absorbed by plants and animals from the air during respiration. The plants return oxygen to the atmosphere during photosynthesis. This links the oxygen cycle to the carbon cycle. Deforestation is likely to gradually reduce the oxygen levels in the atmosphere. Thus, plant life plays an important role in our lives, the enormity of which we frequently fail to appreciate.

3.4.4 The Nitrogen Cycle

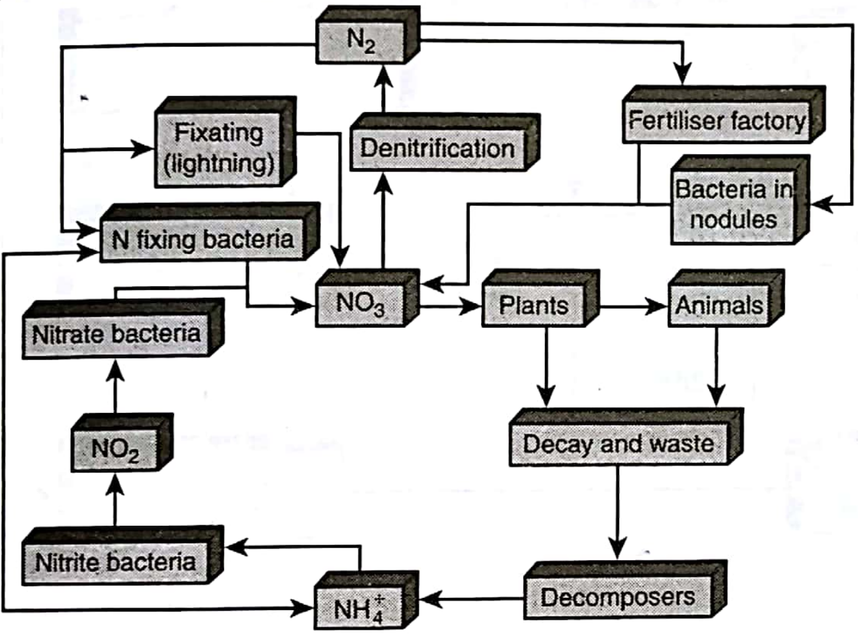


Fig. 3.3 The nitrogen cycle

Nitrogen (N_2) in the atmosphere cannot be directly used as a nutrient by plants or animals. It must be converted into its compound form of ammonia (NH_4), nitrates or nitrites. This occurs through four steps of fixation, nitrification, ammonification and denitrification. Nitrogen fixing bacteria feed off the root nodules of certain plant species such as beans, peas and alfalfa while they fix nitrogen. This nitrogen is then converted into ammonia to be used by those plants. Any unused ammonia undergoes nitrification. In the ammonification step, specialised bacteria and fungi feed and convert dead material (from animals) into compounds such as ammonia and water-soluble salts containing ammonium ions. These compounds are absorbed by plants for growth. In this manner, nutrients are recycled back from animals to plants. Finally, the denitrifcation step completes the nitrogen cycle as nitrogen leaves the soil and is released into the atmosphere as nitrogen or nitrous oxide gas.

It is important to realise that nitrogen-fixing bacteria and fungi in the soil give this important element to plants, which absorb it as nitrates. These nitrates are a part of the plant's metabolism, which help in forming new plant proteins. This is used by the animals that feed on the plants. The nitrogen is then transferred to the carnivores when they feed on the herbivores. So, our own lives are closely interlinked to soil animals, fungi and even the bacteria in the soil. When we think of food webs, we usually think of large mammals and other large forms of life. But we need to understand that it is the unseen small animals, plants and microscopic forms of life that are of great value for the functioning of the ecosystem.

The global nitrogen cycle has been altered due to nitrogen-rich fertilisers used in agriculture, pollution emitted by vehicles and industries and from sewage treatment facilities such as septic tanks which release large amounts of nitrogen into the ground.

3.4.5 The Phosphorus Cycle

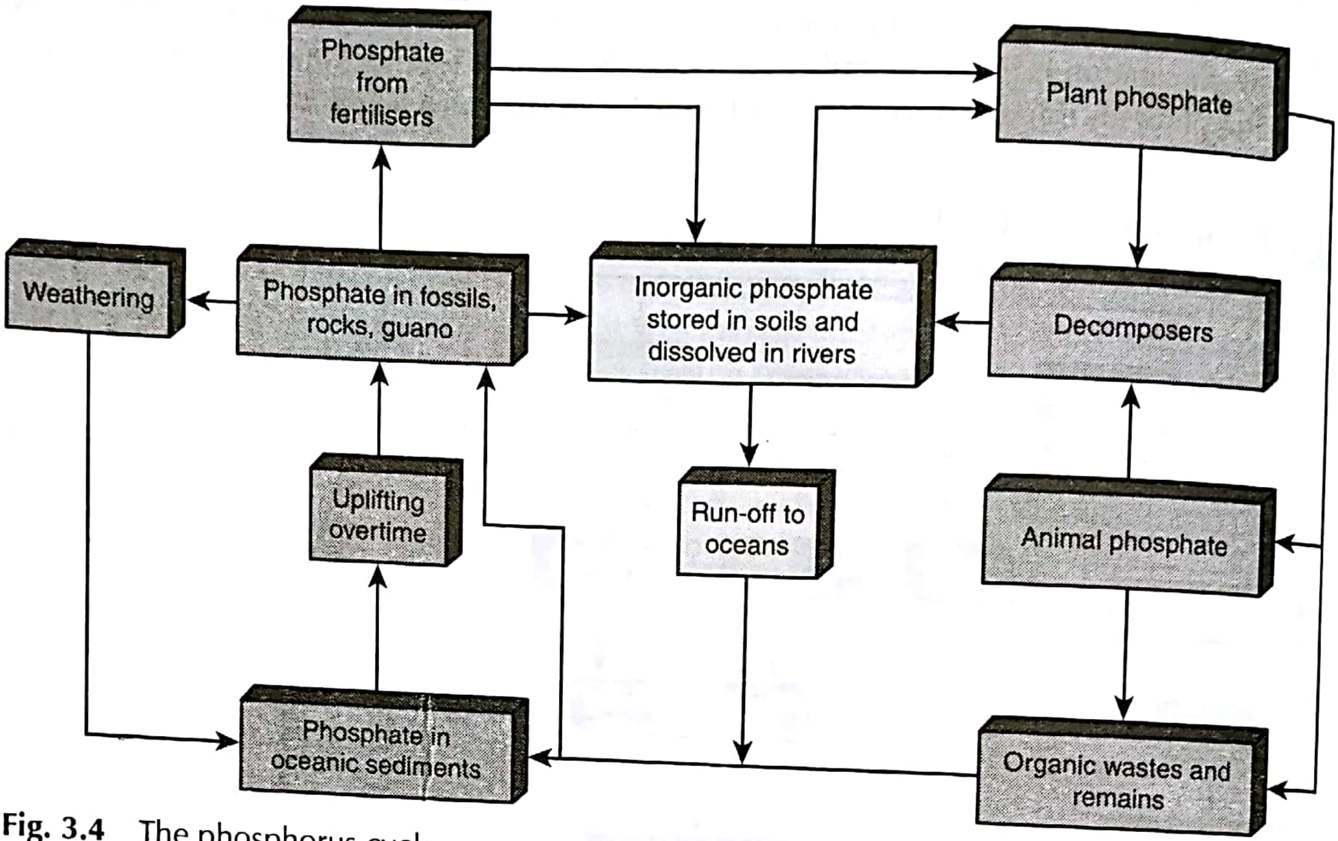

Phosphate from fertilisers
Plant phosphate
Weathering
Phosphate in fossils, rocks, guano
Inorganic phosphate stored in soils and dissolved in rivers
Decomposers
Uplifting overtime
Run-off to oceans
Animal phosphate
Phosphate in oceanic sediments
Organic wastes and remains

Fig. 3.4 The phosphorus cycle

Very little phosphorus enters the earth's atmosphere; it is usually found as part of a phosphate ion in terrestrial rocks or as deposits in ocean bottom sediments. Over time, weathering of rocks brings phosphates into the soil which is then absorbed by plants. Thus, the phosphorus cycle is completed in both land and water. However, most soil contains very little phosphate. It is therefore mined from the earth and added to soil as a fertiliser. Once utilised by plants, it enters the food chain—animals may consume these plants. After death, plant and animal decay allows phosphate to return to the soil. Run-off from rain carries phosphorus back to the ocean or deposits it on rocks, thus completing the phosphorus cycle. Human activities such as phosphate rock mining for commercial fertilisers and detergents have a significant impact in altering the phosphate cycle. Run-off of excess phosphate from the soil pollutes aquatic ecosystems by overloading them with nutrients, which in turn minimises the amount of oxygen available and causes toxic algal blooms.

3.4.6 The Sulphur Cycle

Sulphur enters the earth's atmosphere in the form of hydrogen sulphide (H_2S) and sulphur dioxide (SO_2). H_2S and SO_2 are both emitted from active volcanoes. Additionally, H_2S is released from organic matter that decomposes anaerobically (without oxygen) found in swamps and tidal flats. Other sources of sulphur are sulphate salts that can be found buried under ocean sediments and in underground rocks and minerals. Humans influence the sulphur cycle by burning coal and oil, both containg sulphur, refining sulphur containing petrol and finally through the release of sulphur dioxide by smelting for the extraction of copper, lead and zinc.

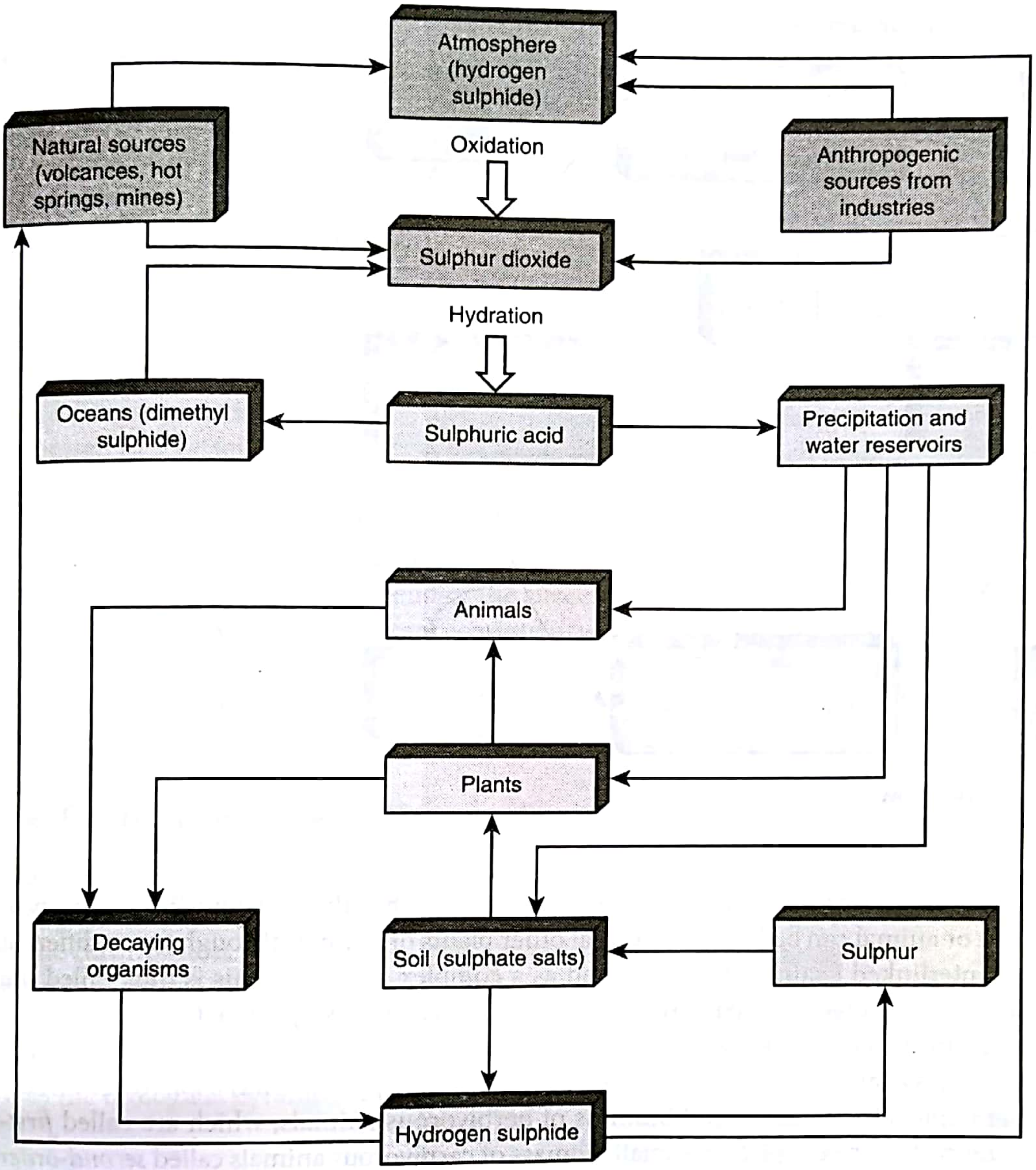

Atmosphere (hydrogen sulphide)
Natural sources (volcances, hot springs, mines)
Anthropogenic sources from industries
Oxidation
Sulphur dioxide
Hydration
Oceans (dimethyl sulphide)
Sulphuric acid
Precipitation and water reservoirs
Animals
Plants
Decaying organisms
Soil (sulphate salts)
Sulphur
Hydrogen sulphide

Fig. 3.5 The sulphur cycle

3.4.7 The Energy Flow

The energy cycle is based on the flow of energy through the ecosystem. The energy from sunlight is converted by plants into growing new plant material, which includes the leaves, flowers, fruit, branches, trunks and roots of plants. Since plants can grow by converting the sun's energy directly into their tissues, they are known as producers in the ecosystem. The plants are used by herbivores as food, which gives them energy. A large part of this energy is used up for the metabolic functions of these animals such as breathing, digesting food, supporting the growth of tissues, maintaining blood flow and body temperature. Energy is also used for activities such as looking for food, finding shelter, breeding and rearing young ones. The carnivores, in turn, depend on the herbivores on which they feed. Thus, different plant and animal species are

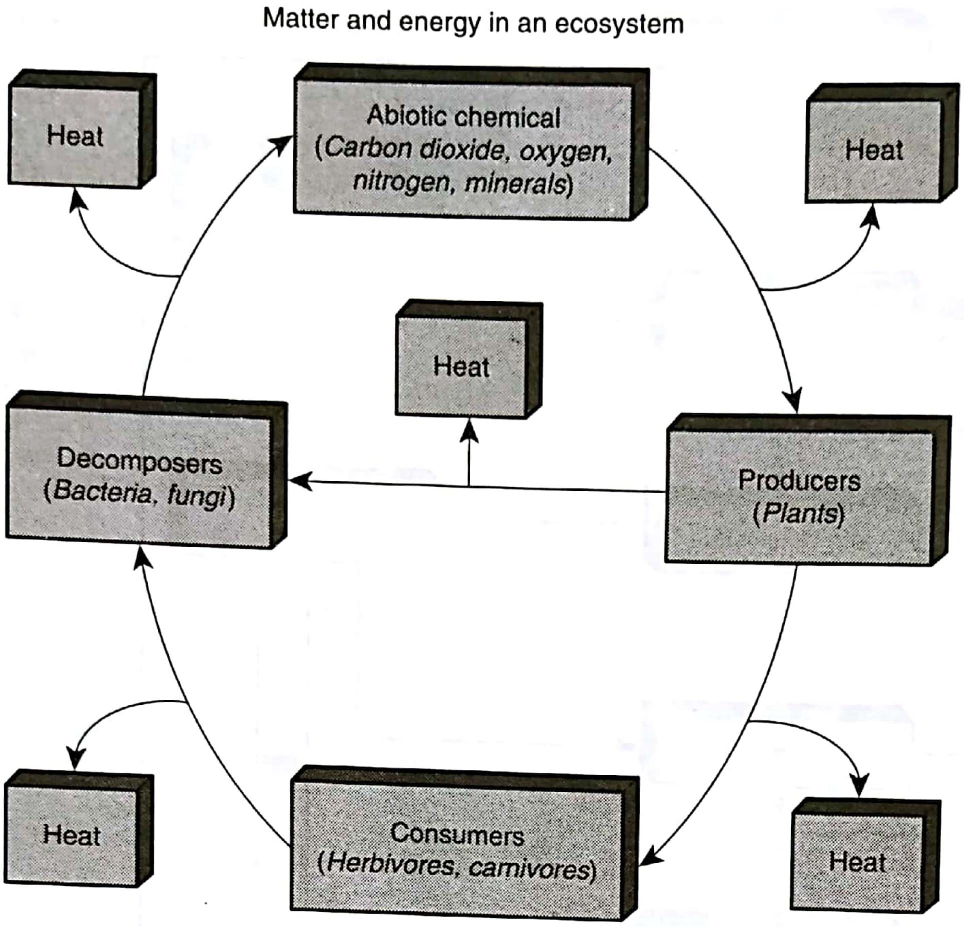

Matter and energy in an ecosystem

Fig. 3.6 Energy flow

linked to one another through *food chains*. Each food chain has three or four links. However, as each plant or animal can be linked to several other plants or animals through many different links, these interlinked chains can be depicted as a complex *food web*. This is thus called the 'web of life' since it shows that there are thousands of interrelationships in nature.

The energy in the ecosystem can be depicted in the form of a *food* or *energy pyramid*. The food pyramid has a large base of plants called producers. The pyramid has a narrower middle section that depicts the number and biomass of herbivorous animals, which are called *first-order consumers*. The apex depicts the small biomass of carnivorous animals called *second-order consumers*. Humans are one of the animals at the apex of the pyramid. Thus, to support mankind, there must be a large base of herbivorous animals and an even greater quantity of plant material.

When plants and animals die, this material is returned to the soil after being broken down into simpler substances by decomposers, such as insects, worms, bacteria and fungi, so that plants can absorb the nutrients through their roots. Animals excrete waste products after digesting food, which goes back to the soil. This links the energy cycle to the nitrogen cycle.

3.4.8 Integration of Cycles in Nature

These cycles are a part of global life processes. These biogeochemical cycles have specific features in each of the ecosystems. These cycles are linked to those of adjacent ecosystems, although their characteristics are specific to the plant and animal communities in the region. This is, in turn, related to the geographical features of the area, the climate and the chemical composition of the soil. Together, the cycles are responsible for maintaining life on earth. If humans disturb these cycles beyond the limits that nature can sustain, they will eventually break down and lead to a degraded earth on which we will not be able to survive.

3.5 ECOLOGICAL SUCCESSION

Ecological succession is a process through which ecosystems tend to change over a period of time. Succession can be related to seasonal environmental changes, which create changes in the community of plants and animals living in the ecosystem. Other successional events may take much longer periods of time, extending to several decades. If a forest is cleared, it is initially colonised by a certain group of species of plants and animals, which gradually change through an orderly process of community development. One can predict that a cleared or open area will gradually be converted into a grassland, a shrubland and finally a woodland and a forest, if permitted to do so without human interference. There is a tendency for succession to produce a more or less stable state at the end of the successional stages. The most frequent example of successional changes occur in a pond ecosystem, where it fluctuates from a dry terrestrial habitat to the early colonisation stage by small aquatic species after the monsoon, which gradually passes through to a mature aquatic ecosystem, and then reverts back to its dry stage in summer when its aquatic life remains dormant.

3.6 FOOD CHAINS, FOOD WEBS AND ECOLOGICAL PYRAMIDS

The transfer of energy from the source in plants through a series of organisms, by eating and being eaten, constitutes the food chain. At each transfer, a large proportion of energy is lost in the form of heat. These food chains are not isolated sequences, but are interconnected. This interlocking pattern is known as the food web. Each step of the food web is called a *trophic level*. These trophic levels together form the ecological pyramid.

3.6.1 The Food Chains

The most obvious aspect of nature is that energy must pass from one living organism to another. When herbivorous animals feed on plants, energy is transferred from the plants to the animals. In an ecosystem, some of the animals feed on other living organisms, while some feed on dead organic matter; the latter form the detritus of the food chain. At each link in the chain, a large part of the energy from the food is lost through daily activities. Each chain usually has only four to five such links. However, a single species may be linked to a large number of species.

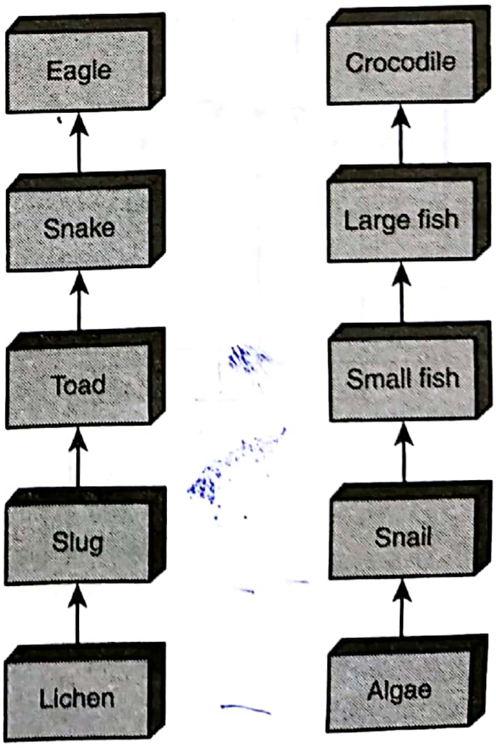


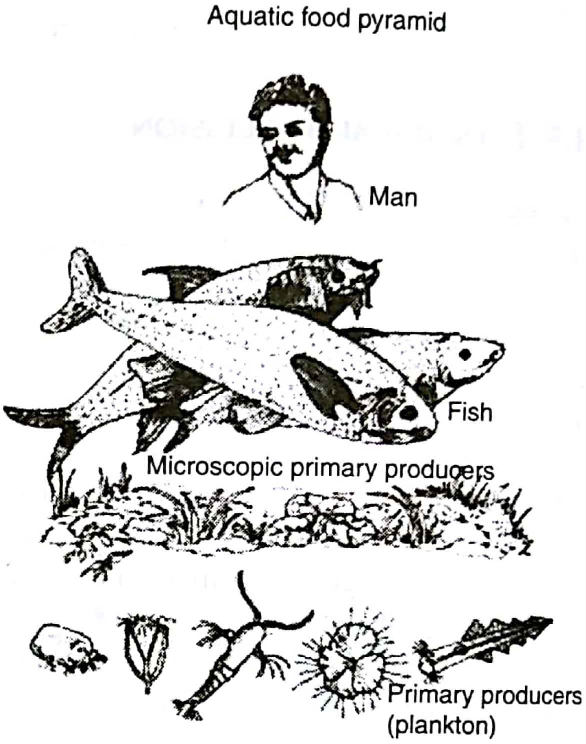
Fig. 3.7 Simple food chains

3.6.2 The Food Webs

In an ecosystem, there are a very large number of interlinked chains; together, these form a food web. If the links in the chains that make up the web of life are disrupted due to human activities that lead to the loss or extinction of species, the web breaks down.

3.6.3 The Ecological Pyramids

In an ecosystem, green plants (the producers) utilise energy directly from sunlight and convert it into matter. A large number of these organisms form the most basic or first trophic level of the food pyramid. The herbivores that eat plants are at the second trophic level and are called primary consumers. The predators that feed on them form the third trophic level and are known as secondary consumers. Only a few animals form the third trophic level consisting of the carnivores at the apex of the food pyramid. This is how energy is used by living creatures and flows through the ecosystem from its base to the apex.



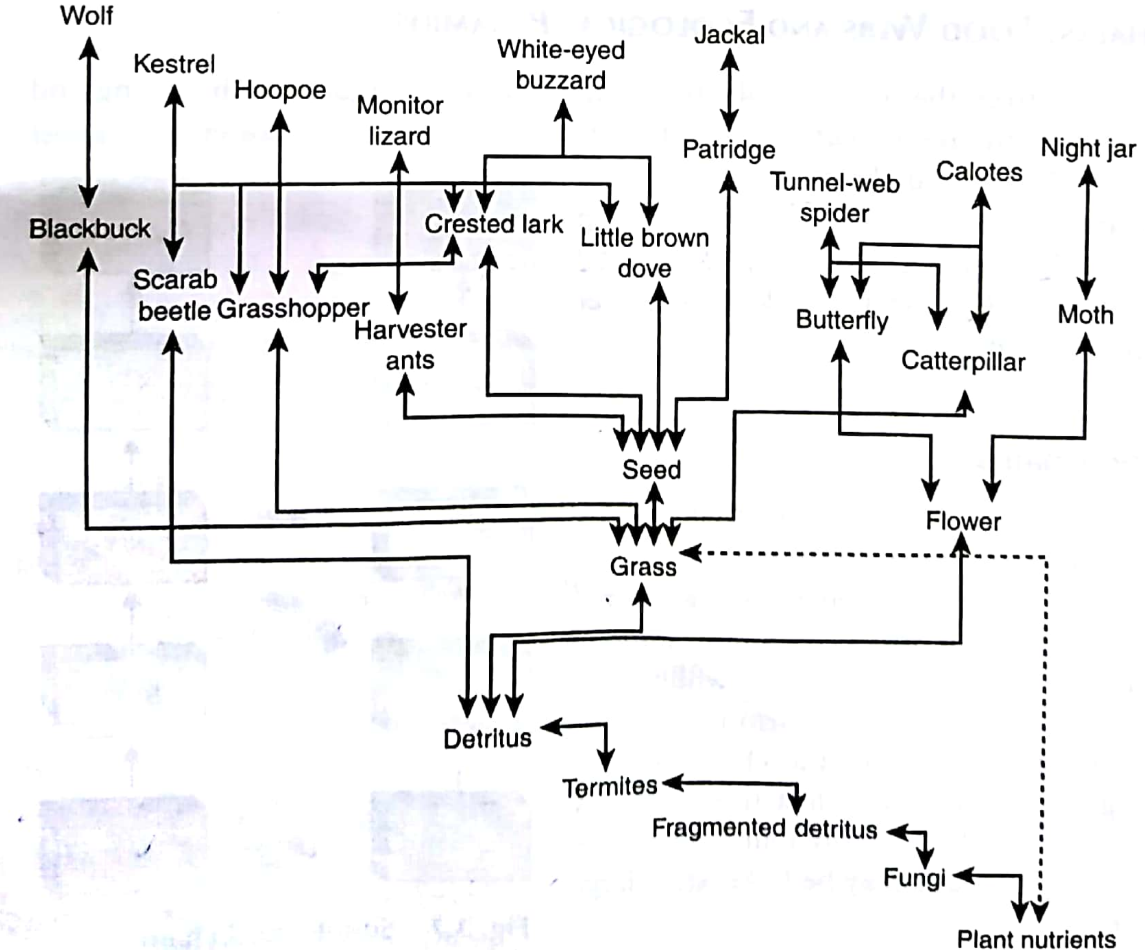


Fig. 3.8 Grassland ecosystem web

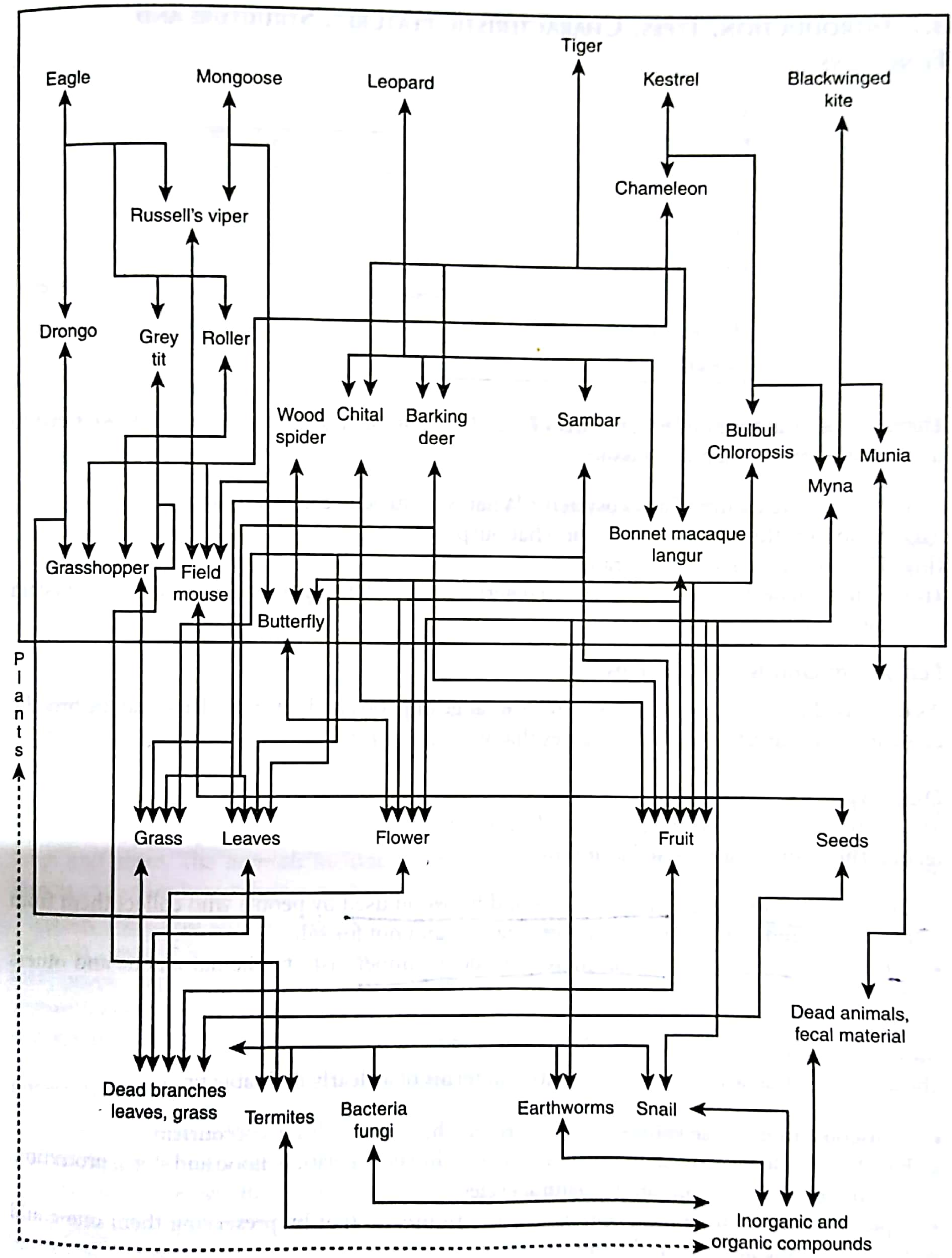


Fig. 3.9 Forest ecosystem web

3.7 INTRODUCTION, TYPES, CHARACTERISTIC FEATURES, STRUCTURE AND FUNCTIONS

Table 3.1 Types of ecosystems

Terrestrial ecosystems	Aquatic ecosystems
Forest	Pond
Grassland	Lake
Semi-arid areas	Wetland
Deserts	River
Mountains	Delta
Islands	Marine

There are several types of ecosystems (Table 3.1). For each of these ecosystems, we need to understand four fundamental issues:

(i) What is the nature of an ecosystem? What is its structure and function?
(ii) Who uses the ecosystem and for what purpose?
(iii) How is this ecosystem degraded?
(iv) What can be done to protect it from deteriorating in the long term? How can the ecosystem be conserved?

Ecosystem Goods and Services

As discussed in Unit 1, ecosystems provide a range of goods and services. These can be broadly categorised as direct and indirect values that we benefit from.

Direct values

These are resources that people depend upon directly and are easy to quantify in economic terms. They can be categorised as follows:

- Consumptive use value—fruit, fodder and firewood used by people who collect them from their surroundings, for their own personal use and not for sale.
- Productive use value—the commercial value of timber, fish, medicinal plants, and others that people collect for sale.

Indirect values

These are uses that are not easy to quantify in terms of a clearly definable price.

- Non-consumptive use value—scientific research, bird-watching, ecotourism.
- Functional value—ecosystem functions such as climate regulation, flood and storm protection, erosion prevention, maintaining natural cycles.
- Option value—maintaining options for the future, so that by preserving them one could reap economic benefits in the future.
- Existence value—the ethical and emotional aspects of the existence of wildlife and nature.

3.7.1 Forest Ecosystems

Forests are formed by a community of plants, which is predominantly structurally defined by its trees, shrubs, climbers and ground cover. Natural vegetation looks and is vastly different from a group of planted trees in orderly rows. The most 'natural' undisturbed forests are located mainly in national parks and wildlife sanctuaries. The landscapes that make up various types of forests look very different from each other. Their distinctive appearance is one of the fascinating aspects of nature. Each forest type forms a habitat for a specific community of animals that are adapted to live in it.

What is a Forest Ecosystem?

A forest ecosystem has two parts:

- *The non-living or abiotic aspects of the forest*: The type of forest depends on the abiotic conditions at the site. Forests on mountains and hills differ from those along river valleys. The vegetation is specific to the amount of rainfall and local temperature, which vary according to latitude, altitude and soil type.
- *The living or biotic aspects of the forest*: The plants and animals form communities that are specific to each forest type. For instance, coniferous trees occur in the Himalayas; mangrove trees in river deltas; thorn trees in arid areas. The snow leopard lives in the Himalayas, while the leopard and tiger live in the forests in the rest of India. Wild sheep and goats live high up in the Himalayas and many of the birds of the Himalayan forests are different from those in the rest of India. The evergreen forests of the Western Ghats and Northeast India have the richest diversity of plant and animal species.

The biotic component includes both large (macrophytes) and microscopic plants and animals.

Plants include the trees, shrubs, climbers, grasses and herbs in the forest. These include species that flower (angiosperms) and are non-flowering (gymnosperms) such as ferns, bryophytes, fungi and algae. The *animals* include species of mammals, birds, reptiles, amphibians, fish, insects and other invertebrates and a variety of microscopic animals.

As the plant and animal species are closely dependent on each other, together they form different types of forest communities. Humans are a part of these forest ecosystems and the local people depend directly on the forest for several natural resources that act as their life-support systems. People who do not live in the forest buy forest products such as wood and paper extracted from the forest. Thus, they use forest produce indirectly from the market.

Forest Types in India

The forest type depends on abiotic factors such as the climate and soil characteristics of a region. Forests in India can be broadly divided into coniferous forests and broad-leaved forests.

They can also be classified according to the nature of their tree species—evergreen, deciduous, xerophytes or thorn trees, mangroves and so on. They can also be classified according to the most abundant species of trees, such as sal or teak forests. In many cases, a forest is named after the first three or four most abundant tree species.

Coniferous forest

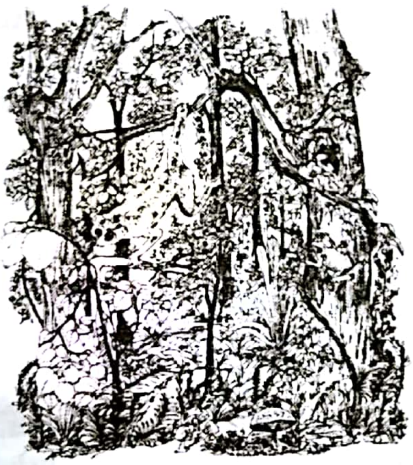
Coniferous forests grow in the Himalayan mountain region, where the temperatures are low. These forests have tall stately trees with needle-like leaves and downward-sloping branches, so that the snow can slip off the branches. They have cones instead of seeds and are called gymnosperms.

Broad-leaved forests are of several types, such as evergreen forests, deciduous forests, thorn forests, and mangrove forests. Broad-leaved trees usually have large leaves of various shapes and are found in the middle to lower latitudes.

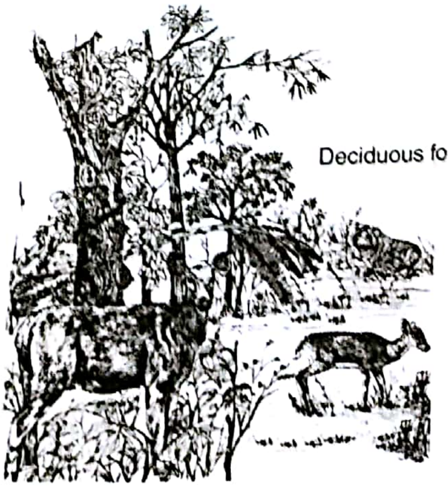
Broadleaved forest

Evergreen forests grow in the high rainfall areas of the Western Ghats, Northeastern India and the Andaman and Nicobar Islands. These forests grow in areas where the monsoon lasts for several months. Some places even get two monsoons, such as in Southern India. Evergreen plants shed a few of their leaves throughout the year. There is no dry leafless phase as in the case of deciduous forests. So an evergreen forest looks green throughout the year. The trees overlap with each other to form a continuous canopy. Thus, very little light penetrates down to the forest floor. Only a few shade-loving plants can grow in the ground layer in areas where some light filters down from the closed canopy. The forest is rich in orchids and ferns. The barks of the trees are covered in moss. The forest abounds in animal life and is very rich in insect life.

Evergreen forest

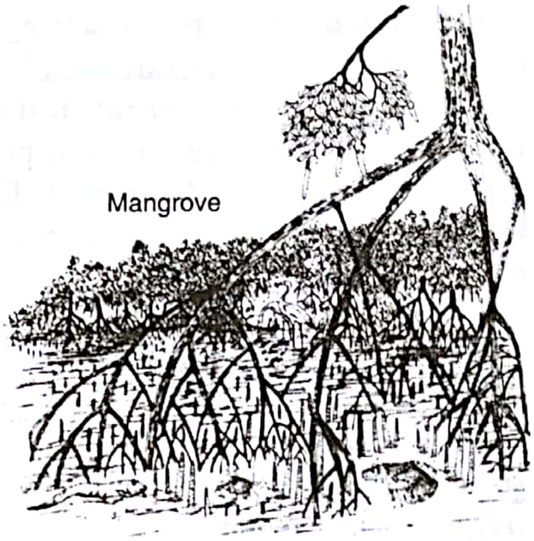


Deciduous forests are found in regions with a moderate amount of seasonal rainfall that lasts for only a few months. Most of the forests in which teak trees grow are of this type. The deciduous trees shed their leaves during the winter and hot summer months. In March or April they regain their fresh leaves just before the monsoon, when they grow vigorously in response to the rains. Thus, there are periods of leaf-fall and canopy regrowth. The forest frequently has thick undergrowth as light can penetrate easily onto the forest floor.



Deciduous forest

Thorn forests are found in the semi-arid regions of India. The trees, which are sparsely distributed, are surrounded by open grassy areas. Thorny plants, called xerophytic species, are able to conserve water. Some of these trees have small leaves, while other species have thick, waxy leaves to reduce water loss during



transpiration. Thorn-forest trees have long or fibrous roots to enable them to reach water at great depths. Many of these plants have thorns, which reduce water loss and protect them from herbivores.

Mangrove forests grow along the coast, especially in the river deltas. These plants are uniquely adapted to be able to grow in a mix of saline and freshwater. They grow luxuriantly in muddy areas covered with silt that the rivers have brought down. They have breathing roots that emerge from the mudbanks.

Forest utilisation

Natural forests provide local people with a variety of products, if the forest is used carefully. The forest products collected by people include food like fruit, roots, herbs and medicinal plants. People depend on fuelwood to cook food, collect fodder for domestic animals and cut building material for housing, medicinal plants that have been known for generations to treat several ailments, and use a variety of NTFPs such as fibre, cane and gum to make household articles.

Table 3.2 Forest communities

Forest type	Plants (examples)	Common animals (examples)	Rare animals (examples)
Himalayan coniferous	Pine, deodar	Wild goats and sheep, Himalayan black bear	Snow leopard, *hangul*, Himalayan brown bear, musk deer, Himalayan wolf
Himalayan broad-leaved	Maple, oak		
Evergreen North-east, Western ghats, Andaman and Nicobar	Jamun, ficus, Dipterocarpus	Tiger, leopard, *sambar*, Malabar whistling thrush, Malabar pied hornbill, tree frogs	Pigmy hog, rhinocerous, lion-tailed macaque
Deciduous-dry	Teak, *ain*, terminalia	Tiger, *chital*, barking deer, babblers, flycatchers, hornbills	
Deciduous-moist	Sal		
Thorn and scrub, semi-arid forests	*Ber*, babul, neem lizard	Blackbuck, *chinkara*, four-horned antelope, partridge, monitor lizard	Bustard, florican
Mangrove delta forests	Avicenia	Crocodiles, shorebirds such as sandpipers, plovers, fish, crustaceans	Water monitor lizard

Woods from different species of trees are put to a variety of uses. For instance, softwood is used for the yoke of a bullock cart while hardwood is used for its axle.

These forest products are of great economic value as they are collected, sold and marketed. Forest dwellers and agricultural people use these goods directly, while other people get them indirectly from the market. Traditional types of agriculture need forest material like branches and leaves, which are burnt to form wood-ash which acts as a fertiliser for crops such as rice.

Forest services include the control of the flow of water in streams and rivers. Forest cover reduces the surface run-off of rainwater and allows groundwater to be stored. Forests also prevent the erosion of soil. Once soil is lost by erosion, it can take thousands of years to re-form. Forests also regulate the local temperature. It is cooler and more moist under the shade of the trees in the forest. Most importantly, forests absorb carbon dioxide and release oxygen that we require to breathe.

The wild relatives of crop plants and fruit trees have special characteristics which are used to develop new crops and newer varieties of fruit. These newer varieties give greater yields or are more resistant to diseases. New industrial products are being produced from the wild plants of the forest. Many of our new medicines come from wild plants.

Direct uses of forest products

- Fruits: Mango, *jamun*, *amla*
- Roots: Dioscoria
- Medicine: Gloriosa, foxglove
- Fuelwood: Many species of trees and shrubs
- Small timber for building huts and houses
- Wood for farm implements
- Bamboo and cane for baskets
- Grass for grazing and stall feeding livestock

Indirect uses of forest products

- Building material for construction and furniture for the urban sector
- Medicinal products collected and processed into drugs
- Gums and resins processed into a variety of products
- Raw material for industrial products and chemicals
- Paper from bamboo and softwoods

What are the Threats to the Forest Ecosystem?

As forests grow very slowly, we cannot use more resources than they can produce during a growing season. If timber is felled beyond a certain limit, the forest cannot regenerate. The gaps in the forest change the habitat quality for animals, and the more sensitive species cannot survive under these changed conditions. Over-utilising forest resources for fuelwood or timber and conversion to monoculture plantations for timber or other products impoverishes the local people as the economic benefit usually accrues to people who live elsewhere. The entire resource base on which local people have traditionally survived for generations, gets rapidly destroyed. Eventually, the forest is completely degraded, impacting other forest functions. For example, the loss of forest cover leads to irreversible changes such as soil erosion, large run-off of surface water during monsoons leading to flash-floods and a shortage of water once the monsoon is over. Other threats such as illegal extraction of wood from many forests result in similar problems of forest degradation.

Developmental activities such as rapid population growth, together with urbanisation, industrialisation and the increasing use of consumer goods, lead to the over-utilisation of forest produce. The forests are rapidly shrinking as the need for agricultural land increases. It is estimated that India's forest cover has decreased from about 33% to 11% in the last century. The increasing use of wood for timber, wood-pulp for paper and the extensive use of fuelwood result in continual forest loss. Forests are also lost by mining and building dams. As the forest resources are exploited, the forest canopy is opened up, the ecosystem is degraded, and its wildlife is seriously threatened. As the forest is fragmented into small patches, wild plant and animal species become extinct. And these can never be brought back.

CASE STUDY 1

Threats to Kudremukh National Park in Karnataka

Kudremukh, a tropical wet evergreen-type forest of the Western ghats, extends to over 600 square kilometres and provides a habitat for the three big carnivores – tiger, leopard and wild dog – amongst several other species such as the lion-tailed macaque and wild boar. Mining continues to be a threat to this national park, even though the Supreme Court placed an order in 2005 to shut down all such operations and to restore all degraded land in the forest area. However, the mining lobby and state government agencies have still not restored the degraded forest land. Furthermore, illegal storage and maintenance of mining equipment in Kudremukh indicates the unwillingness of the state government to stop mining operations.

What if the Forests Disappear?

When forests are cut, tribal people who depend directly on them for food and fuelwood and other products find it very difficult to survive. Agricultural people do not get enough fuelwood and small timber for making houses and farm implements. Urban people depend on food from agricultural areas, which in turn depend on neighbouring forest ecosystems, and they have to pay higher prices for food as the human population increases.

The insects that live and breed in the forest such as bees, butterflies and moths decrease in number once forests are degraded. As their numbers decrease, they are unable to effectively pollinate agricultural crops and fruit trees. This leads to a decline in agricultural yield.

The rain that falls on deforested land flows directly into nearby rivers. Thus, water is not retained underground and people do not get a sufficient supply of water throughout the year. The exposed soil is rapidly washed away during the rains once the protective forest cover is removed, seriously affecting agriculture in such areas. In deforested areas, the water in streams is brown in colour as the soil is washed away, while the water in forested streams is crystal clear.

In addition, wild animals lose their habitat, leading to the extinction of many precious species. The residual forests must be protected from being destroyed any further if all the diverse species of plants and animals are to be protected for future generations.

CASE STUDY 2

Maharashtra floods 2005

Many parts of Maharashtra, including Mumbai, were impacted by severe flooding on 26 July 2005. The floods were caused by heavy torrential rain; Mumbai was lashed with 994 mm (39.1 inches) of rain which lasted 24 hours and continued erratically the next day. At least 5000 people died and thousands of people were left stranded on the road with their homes inundated. The entire city came to a standstill. Amongst other causes such as clogged and insufficient drainage systems, the large-scale destruction of mangroves and wetlands along the coastline was a major contributor to the magnitude of damage in terms of lives and property. These mangroves and wetlands would otherwise have provided for a natural barrier against flooding and reduced the strength of the waves.

How can Forest Ecosystems be Conserved?

We can conserve forests only if we use the resources carefully. This can be done by leading sustainable lifestyles. Some examples include using non-wood products in homes, re-using paper and using alternative sources of energy instead of fuelwood. Further, there is a need to grow more trees to replace those that are cut down from forests every year for timber. Afforestation needs to be done continuously, from which fuelwood and timber can be judiciously used.

The natural forests with all their diverse species must be protected as national parks and wildlife sanctuaries where plants and animals can be preserved.

3.7.2 Grassland Ecosystems

These include a wide range of landscapes in which the vegetation is predominantly grass and small annual plants specifically adapted to India's climatic conditions.

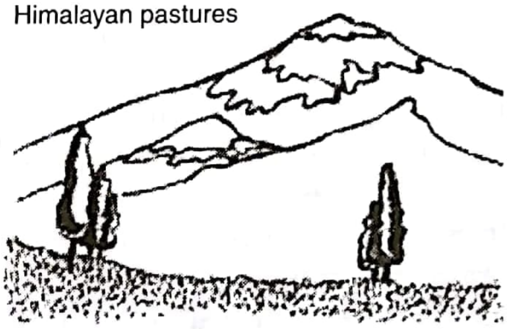
What is a Grassland Ecosystem?

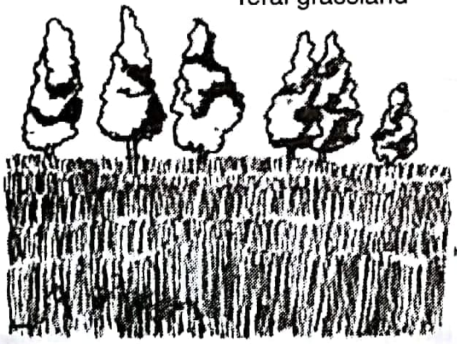
Grasslands cover areas where rainfall is usually low and/or soil depth and quality is poor. The low rainfall prevents the growth of a large number of trees and shrubs, but is sufficient to support the growth of grass cover during the monsoon. Many grasses and other small herbs become dry and the exposed portion of the plant above the ground dies in summer. In the next monsoon, the grass cover grows back from the root-stock and the seeds of the previous year. This change gives grasslands a highly seasonal appearance, with periods of increased growth being followed by a dormant phase.

A variety of grasses, herbs and several species of insects, birds and mammals have evolved so that they are adapted to these wide-open grass-covered areas. These animals can live in conditions where food is plentiful after the rains, so they can store this as fat for use during the dry period when there is very little to eat. Humans began to use these grasslands as pastures to feed livestock when animals were domesticated and thus became pastoralists in ancient times.

Types of grasslands in India: Grasslands form a variety of ecosystems located in different climatic conditions, ranging from near-desert conditions to patches of shola grasslands that occur on hill-slopes alongside the extremely moist evergreen forests in South India. In the Himalayas, there are the high cold pastures. There are tracts of tall elephant grass in the low-lying *terai* belt south of the Himalayan foothills. There are also semi-arid grasslands in Western India, parts of Central India and in the Deccan plateau.

The *Himalayan pasture belt* extends up to the snowline; the grasslands at a lower level form patches along with coniferous or broad-leaved forests. Himalayan wildlife requires both forest and grassland ecosystems as vital parts of their habitat. The animals migrate up into the high-altitude grasslands in the summer and move down into the forest in the winter when the snow covers the grasslands. These Himalayan pastures have a large variety of grasses and herbs. The Himalayan hill-slopes are covered with thousands of colourful flowering plants as well as a large number of medicinal plants.


Himalayan pastures

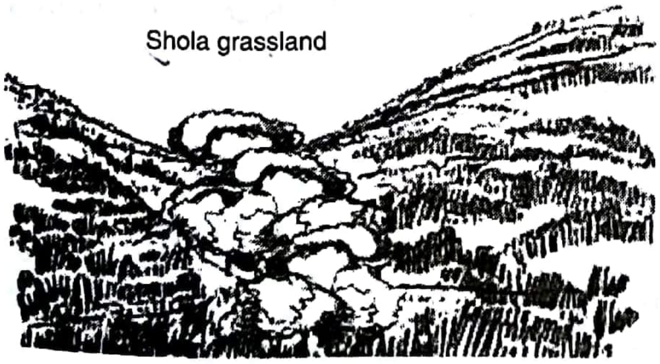

Terai grassland

The *terai* consists of patches of tall grasslands interspersed with sal forest ecosystems. The patches of tall elephant grass, which grow to a height of about five metres, are located in the low-lying waterlogged areas. The sal forest patches cover the elevated regions and the Himalayan foothills. The *terai* also includes marshes in low-lying depressions. This ecosystem extends in a belt south of the Himalayan foothills.

The *semi-arid plains of Western India, Central India and the Deccan* are covered by grassland tracts with patches of thorn forest. Several mammals such as the wolf, blackbuck, *chinkara* and birds such as bustards and floricans are adapted to these arid conditions. The scrublands of the Deccan plateau are covered with seasonal grasses and herbs on which its fauna is dependent. It teems with insect life on which the insectivorous birds feed.

Semiarid grassland

The *shola grasslands* consist of patches on hill-slopes that occur alongside the *shola* forests on the Western ghats, the Nilgiri and Anamalai ranges. These form patchworks of grassland on the slopes and forest habitats along the streams and low-lying areas.


Shola grassland

Grasslands are not restricted to low-rainfall areas. Certain grassland types form when clearings are made in different forest types. Some are located on the higher, steep hill-slopes with patches of forest that occur along the streams and in depressions. The grasslands are related to repeated fires that do not permit the forest to grow.

Grasses are the main producers of biomass in these regions. Each grassland ecosystem has a wide variety of species of grasses and herbs. Some grass and herb species are more sensitive to excessive grazing and are suppressed if the area is over-grazed. Others are destroyed by repeated fires and cannot regenerate. Thus over-used or frequently burnt grasslands are degraded and are poor in plant species diversity.

How are grasslands used?

Grasslands are the grazing areas of many rural communities. Farmers who keep cattle or goats and shepherds who keep sheep, are highly dependent on grasslands to supply food for their livestock. Fodder is collected and stored to feed cattle when there is no grass left for them to graze in summer. Further, grasslands maintain biodiversity, serve as a storehouse for carbon and provide for recreational use and wildlife viewing. Grass is also used to thatch houses and farm-sheds. The thorny bushes and branches of the few trees that are seen in grasslands are used as the main source of fuelwood.

What are the threats to grassland ecosystems?

In many areas, grasslands have been used for centuries by pastoral communities. Over-utilisation and changes in use of the 'common grazing lands' of rural communities has led to their degradation. Grasslands have a limited ability to support domestic animals and wildlife. When animals over-graze, the grasses are converted into flat stubs with very little green matter. Degraded grasslands have fewer grass species as the nutritious species are entirely used up by the large number of domestic animals and are thus unable to regenerate. Therefore, increasing the number of domestic animals reduces the 'naturalness' of the grassland ecosystem, leading to its deterioration. The grassland cover in the country, in terms of permanent pastures, is only 3.7% of the total land (Food and Agriculture Organisation, 2002).

Other than over-grazing, another major threat to natural grasslands is their conversion into irrigated farmlands. In the Deccan, grasslands have been converted to irrigated farms and are now mainly used to grow sugarcane, which is a water-intensive crop. After continuous irrigation, such land becomes saline and useless in a few years. More recently, many of these residual grassland tracts have been converted into industrial areas. This provides short-term economic gains but results in long-term economic and ecological loss. Other human activities such as fires also affect grasslands adversely. When fires are lit in the grasslands in summer, the burnt grass gets a fresh flush of small green shoots which the domestic animals graze on. If this is done too frequently, the grasslands begin to deteriorate. Finally, the grasslands become bare; the soil is solidly compacted by trampling, or is washed away during the monsoon by rain and whipped into dust storms during the hot dry summer. The land is degraded, as there is no grass to hold the soil in place. It becomes a wasteland.

Why are our grassland species vanishing?

Most people think that it is only our forests and its wildlife that is disappearing. However, other natural ecosystems, such as grasslands, are disappearing even more rapidly.

Many of the grassland species have disappeared from several parts of India in which they were found 50 or 60 years ago. The cheetah is extinct in India; the wolf is now highly threatened; the blackbuck and *chinkara* are being poached for their meat; birds such as the beautiful great Indian bustard are vanishing. Unless grassland species are protected, they will vanish from their shrinking habitat, as natural and undisturbed grasslands are left in very few locations. If these animals and birds are killed or their habitat is reduced further, their extinction will rapidly follow.

What if our grasslands disappear?

If our grasslands are destroyed, we will lose a highly-specialised ecosystem to which plants and animals adapted themselves over millions of years. In addition, the local people will not be able to support their livestock herds.

The extinction of species is a great loss to humankind. The genes of wild grasses are extremely useful for developing new crop varieties. New medicines could well be discovered from wild grassland plants. It is possible that genes from wild herbivores like wild sheep, goat and antelope may be used for developing new strains of domestic animals. All these possibilities will be lost along with the grasslands.

How can grassland ecosystems be conserved?

Grasslands should not be over-grazed and some areas should be closed for grazing. It is better to collect grass for stall-feeding cattle. A part of the grassland in an area must be closed every year, so that a rotational grazing pattern is established. Fires must be prevented and rapidly controlled. In hilly areas, soil and water management in each micro-catchment will help the grassland to return to a natural, highly-productive ecosystem.

To protect the most natural undisturbed grassland ecosystems, sanctuaries and national parks must be created. Their management should focus on preserving all their unique species of plants and animals. Thus, they should not be converted into plantations of trees. The open grassland is the habitat of its specialised fauna. Planting trees in these areas reduces the natural features of this ecosystem, resulting in the destruction of this unique habitat for wildlife.

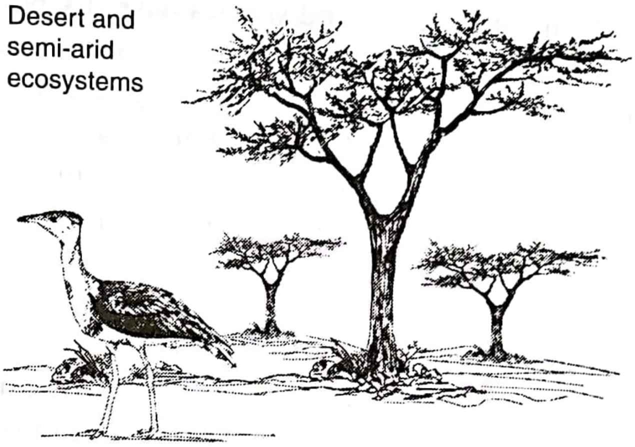
What should we do?

- There is a pressing need to preserve the few natural grassland areas that still survive by creating national parks and wildlife sanctuaries in the different types of grasslands.
- Animals such as the wolf, blackbuck, *chinkara* and birds such as the bustard and florican have now become rare. They must be carefully protected in the few national parks and wildlife sanctuaries that have natural grassland habitats as well as outside these PAs.
- We need to create awareness among people that grasslands are of great value. If we are all concerned about our disappearing grasslands and their wonderful wildlife, the Government will be motivated to protect them.
- Keeping grasslands alive should be made a national priority.

3.7.3 Desert Ecosystems

Desert and semi-arid lands are extremely specialised and sensitive ecosystems that are easily destroyed by human activities. The plants and animals that inhabit these dry areas can live only in this ecosystem.

What is a Desert or Semi-Arid Ecosystem?



Deserts and semi-arid areas are mainly located in Western India and the Deccan plateau. The climate in these vast tracts is extremely dry. Cold deserts such as in Ladakh, located in the high plateaus of the Himalayas, also exist. The most typical desert landscape seen in Rajasthan is in the Thar desert. This has sand dunes; it also has areas covered with sparse grasses and a few shrubs, which grow if it rains. In most areas of the Thar, rainfall is scanty and sporadic. In some areas, it may rain only once every few years. In the adjoining semi-arid tract, the vegetation consists of a few shrubs and thorny trees such as *kher* and *babul.*

The Great and Little Rann of Kutch are extraordinarily specialised arid ecosystems. In summer, they are similar to a desert landscape. However, as these are low-lying areas near the sea, they are converted to salt marshes during the monsoons. During this period, they attract an enormous number of aquatic birds such as ducks, geese, cranes and storks. The Great Rann is famous, as it is the only known breeding colony of the greater and lesser flamingos in our country. The Little Rann of Kutch is the only home of the wild ass in India.

Desert and semi-arid regions have a number of highly-specialised insects and reptiles. The rare animals include the Indian wolf, desert cat, desert fox and birds such as the great Indian bustard and florican. Some of the more common birds include the partridge, quail and sand-grouse.

How are desert and semi-arid ecosystems used?

Areas of scanty vegetation with semi-arid scrubland have been used for camel, cattle and goat grazing in Rajasthan and Gujarat, and for sheep grazing in the Deccan plateau.

Areas that have a little moisture, for example along the watercourses, have been used for growing crops such as *jowar* (sorghum) and *bajra* (millet). The natural grasses and local varieties of crops have adapted to growing at very low moisture levels. These can be used for genetic engineering and developing semi-arid land crops for the future.

What are the threats to desert ecosystems?

Several types of development strategies as well as human population growth have begun to affect the natural ecosystem of the desert and semi-arid lands. The conversion of these lands through extensive irrigation systems has changed several of the natural characteristics of this region. Canal water evaporates rapidly bringing the salts to the surface. The region becomes highly unproductive as it becomes saline. The over-extraction of groundwater from tube wells lowers the water table, creating an even drier environment. Thus, human activities are destroying the authenticity of this unique ecosystem. The special species that evolved here over millions of years may soon become extinct.

How can desert ecosystems be conserved?

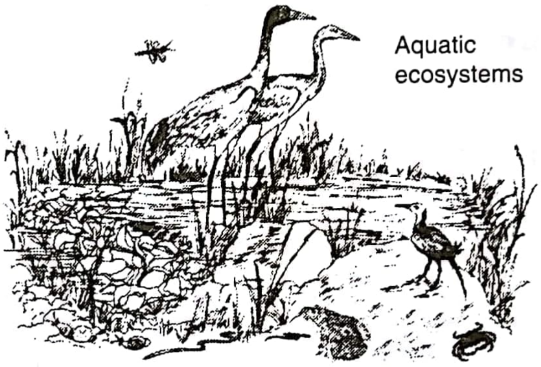
Desert ecosystems are extremely sensitive. Their ecological balance that forms a habitat for their plants and animals is easily disturbed. Desert people have traditionally protected their meagre water resources. The Bishnoi tribe in Rajasthan is known to have protected their *khejdi* trees and the blackbuck antelope for several generations. The tradition began when the ruler of their region ordered his army to cut down trees for his own use. Several Bishnois were said to have been killed while trying to protect their trees.

There is a pressing need to protect residual patches of this ecosystem within national parks and wildlife sanctuaries in desert and semi-arid areas. The Indira Gandhi canal in Rajasthan is destroying this important natural arid ecosystem, as it will convert the region into intensive agriculture. In Kutch, areas of the little Rann, which is the only home of the wild ass, will be destroyed by the spread of salt works.

Development projects alter the desert and arid landscape. There is a sharp reduction in the habitat available for its noteworthy species, bringing them to the verge of extinction. We need a sustainable form of development that takes the special needs of the desert into account.

3.7.4 Aquatic Ecosystems

The aquatic ecosystems comprise the marine environments of the sea and freshwater systems in lakes, rivers, ponds and wetlands.


Aquatic ecosystems

What is an Aquatic Ecosystem?

In aquatic ecosystems, plants and animals live in water. These species are adapted to live in different types of aquatic habitats. The special abiotic features are its physical aspects such as the quality of the water, which includes its clarity, salinity, oxygen content and rate of flow. Aquatic ecosystems may be classified as being *stagnant* ecosystems or *running water ecosystems*. The mud, gravel or rocks that form the bed of the aquatic ecosystem alter its characteristics and influence its plant and animal species composition. Aquatic ecosystems are also classified into *freshwater, brackish* and *marine* ecosystems, which are based on the salinity levels.

The freshwater ecosystems that have running water are streams and rivers. Ponds, tanks and lakes are ecosystems where water does not flow. *Wetlands* are special ecosystems in which the water level fluctuates dramatically in different seasons. They have expanses of shallow water with aquatic vegetation, which forms an ideal habitat for fish, crustaceans and water birds.

Marine ecosystems are highly saline, while brackish areas have less saline water such as in river deltas. *Coral reefs* are very rich in species and are found in only a few shallow tropical seas. The richest coral reefs in India are around the Andaman and Nicobar islands and in the Gulf of Kutch.

Table 3.3 Types of aquatic ecosystems

Fresh water ecosystems		Marine ecosystems	
Flowing water (examples)	Still water (examples)	Brackish water (examples)	Saline water (examples)
Streams, rivers	Ponds, deltas, wetlands, lakes	Coastal	Deep ocean, shallows, coral reefs

Brackish water ecosystems in river deltas are covered by mangrove forests and are among the world's most productive ecosystems in terms of biomass production. The largest mangrove swamps are in the Sunderbans in the delta of the Ganges river.

Pond ecosystems

The pond is the simplest aquatic ecosystem. There are differences between a temporary pond that has water only in the monsoon season and a larger tank or lake that is an aquatic ecosystem throughout the year. Most ponds become dry after the rains are over and are covered by terrestrial plants for the rest of the year.

When a pond begins to fill during the rains, its life forms, such as algae and microscopic animals, aquatic insects, snails and worms, emerge from the floor of the pond where they remained dormant during the dry phase. Gradually, more complex animals such as crabs, frogs and fish return to the pond. The vegetation consists of floating weeds and rooted vegetation on the periphery, whose roots are in the muddy floor under the water and whose foliage emerges from the surface of the water.

As the pond fills in the monsoon season, a large number of food chains are formed. The algae are eaten by microscopic animals, which are in turn eaten by small fish, on which the larger carnivorous fish depend. These are in turn eaten by birds such as kingfishers, herons and birds of prey. Aquatic insects, worms and snails feed on the waste material excreted by animals and the dead or decaying plant and animal matter. They act on the detritus, which is broken down into nutrients which aquatic plants can absorb, thus completing the nutrient cycle in the pond.

Temporary ponds begin to dry up after the rains and the surrounding grasses and terrestrial plants spread into the moist mud that is exposed. Animals like frogs, snails and worms remain dormant in the mud, awaiting the next monsoon.

Lake ecosystems

A lake ecosystem functions like a giant permanent pond. A large amount of its plant material is algae, which derives energy from the sun. This is transferred to microscopic animals which feed on the algae. Herbivorous fish depend on algae and aquatic weeds. Small animals such as snails are eaten by small carnivorous fish, which in turn are preyed upon by larger carnivorous fish. Some specialised fish, such as catfish, feed on the detritus on the muddy bed of the lake; they are called 'bottom feeders' or 'bottom dwellers'.

Energy cycles through the lake ecosystem from the sunlight that penetrates the water surface to the plants. From the plants, the energy is transferred to herbivorous animals and carnivores. Animals excrete waste products, which settle at the bottom of the lake and are broken down by small animals that live in the mud in the lake bed. This acts as the nutrient material used by aquatic plants for their growth. During this process, plants use carbon from CO_2 for their growth and release oxygen. This oxygen is then used by aquatic animals, which filter water through their respiratory system.

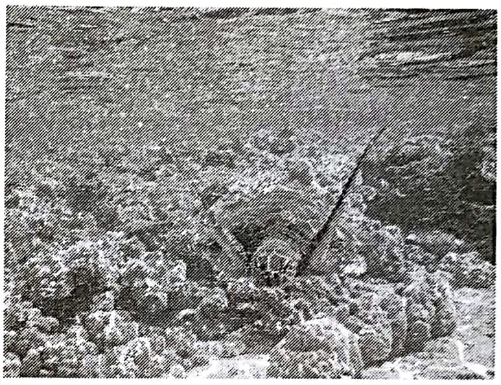
Stream and river ecosystems

Streams and rivers are flowing water ecosystems in which all living forms are specially adapted to different rates of flow. Some plants and animals, such as snails and other burrowing animals, can withstand the rapid flow of hill-streams. Other species, like water beetles and skaters, can live only in slower moving water. Some species of fish, like the Mahseer, move upstream from rivers to hill-streams for breeding. They need crystal clear water to be able to breed.

As deforestation occurs in the hills, the water in the streams that once flowed throughout the year becomes seasonal. This leads to flash-floods during the rains and water shortage when the streams dry up after the monsoon.

The community of flora and fauna of streams and rivers depends on the clarity, flow and oxygen content as well as the nature of their beds. The stream or river can have a sandy, rocky or muddy bed, each type having its own species of plants and animals.

Marine ecosystems


Olive ridley turtle

The Indian Ocean, Arabian Sea and Bay of Bengal constitute the marine ecosystems around peninsular India. In the coastal areas, the sea is shallow while further away it is deep. Both are different ecosystems. The producers in this ecosystem vary from microscopic algae to large seaweeds. There are millions of zooplankton and a large variety of invertebrates which fish, turtles and marine mammals feed on.

The shallow areas near Kutch and around the Andaman and Nicobar islands are some of the most incredible coral reefs in the world. Coral reefs are second only to tropical evergreen forests in their richness of species. Fish, crustaceans, starfish, jellyfish and polyps that deposit coral are just a few of the thousands of species that form this incredible world under the shallow seas.

The deforestation of the adjacent mangroves leads to silt being carried out to sea where it is deposited on the coral, which gets bleached and then dies. There are many types of coastal ecosystems, which are highly dependent on the tide.

The marine ecosystem is used by coastal fisherfolk for fishing, which is their livelihood. In the past, fishing was done at a sustainable level and the marine ecosystem continued to maintain its abundant supply of fish over many generations. Now, with the growth of intensive fishing using giant nets and mechanised boats, the fish catch in the Indian Ocean has dropped significantly.

Seashore ecosystems

Beaches can be sandy, rocky, shell-covered or muddy. On each of these different types, several specific species have evolved to occupy a separate niche. There are different crustaceans, such as crabs, that make holes in the sand. Various shore birds feed on their prey by probing into the sand or mud on the seashore. Several different species of fish are caught by fishermen. In many areas, the fish catch has decreased over the last two decades.

How are Aquatic Ecosystems Used?

Humans use aquatic ecosystems for clean freshwater on which our lives depend. We need clean water to drink and for other domestic uses. Water is usually impounded by large dams to ensure supply throughout the year. Agriculture and industry are highly dependent on these large quantities of water. Further, dams are built across rivers to generate electricity. A large proportion of this energy is used by urban people, by agriculturists in irrigated farmlands and in enormous quantities for industry.

Fisherfolk use the aquatic ecosystems to earn a livelihood. People catch fish and crabs; they also collect edible plants. These are used locally as food or sold in the market. Over-fishing leads to a serious decline in catch and a long-term loss of income for the fisherfolk.

Marshes and wetlands are of great economic importance for people who live on their fish, crustaceans, reeds, grasses and other produce.

What are the Threats to Aquatic Ecosystems?

Water pollution occurs from sewage and poorly-managed solid waste in urban areas when it enters the aquatic ecosystem of lakes and rivers. Sewage leads to a process called *eutrophication*, which destroys life in the water as the oxygen content is severely reduced. Fish and crustaceans cannot breathe and are killed; a foul odour is produced; gradually, the natural flora and fauna of the aquatic ecosystem are destroyed. In rural areas, the excessive use of fertilisers causes an increase in nutrients, which leads to eutrophication. Pesticides used in adjacent fields pollute the water and kill off its aquatic animals. Chemical pollution from industry kills a large number of life forms in adjacent aquatic ecosystems. Contamination by heavy metals and other toxic chemicals affects the health of people who live near these areas as they depend on this water.

Other than water quality, the quantity of water in freshwater ecosystems also poses a significant threat. Dams built across rivers greatly alter the flow of natural river ecosystems, causing some rivers to slowly run dry as they no longer join a sea. Further, changing the nature of an aquatic ecosystem from a flowing water one to a static one destroys the natural biological diversity, causing habitat loss to the species that require running water. In some semi-arid areas that are artificially irrigated, the high level of evaporation leads to severe salinisation as salts are brought up into the surface layers of the soil. Land is therefore eventually rendered unproductive. The social implications of large dams cannot be undermined—all over the world, thousands of people have been displaced and lost their livelihoods because of the construction of large dams.

CASE STUDY 3

Threats to wetlands in Assam

Almost 40% of all wetlands in Assam are under threat. A survey conducted by the Assam Remote Sensing Application Centre (ARSAC), Guwahati, and the Space Research Centre, Ahmedabad, has revealed that 1367 out of 3513 wetlands in Assam are under severe threat due to the invasion of aquatic weeds and several developmental activities. The wetlands of Assam form the greatest potential source of income for the state in terms of fisheries and tourism. Though the wetlands have the capacity to produce 5,000 t/ha/yr of fish, around 20,000 t of fish have to be imported to meet local demands. This is primarily due to poor wetland management.

How can Aquatic Ecosystems be Conserved?

For the sustainable use of an aquatic ecosystem, water pollution must be prevented in the first place, as cleaning up or treating polluted water is a reactive approach.

Healthy rivers must be protected against damming, other options for meeting water and energy needs must be explored. Proper planning and assessment must be carried out to protect dam-affected people to ensure a more equitable distribution of benefits from dams.

Aquatic ecosystems, especially wetlands, need protection by including them in sanctuaries or national parks in the same way in which we protect our natural forests. These sanctuaries in aquatic ecosystems protect a variety of forms of life as well as rare fish which are now highly endangered, such as the Mahseer. Wetland sanctuaries and national parks are of the greatest importance, as they are among the most threatened of our ecosystems.

3.8 DEGRADATION OF ECOSYSTEMS

Ecosystems are the basis of life itself! The natural ecosystems in the wilderness provide a variety of products and are regions in which a number of vital ecological processes are present; without these processes, human civilisation would not be able to exist.

However, ecosystems are frequently disrupted by human actions, leading to the extinction of species of plants and animals that can live only in the different natural ecosystems. Some species, if eliminated, seriously affect the ecosystem. These are called 'keystone' species. Extinction occurs due to changes in land use. Forests are deforested for timber, wetlands are drained to create agricultural land and semi-arid grasslands used as pastures are converted to irrigated fields. The pollution from industries and the waste from urban settings can also lead to the poisoning and extinction of several species.

The reason for the depletion of natural resources is two-fold—our rapidly exploding population that needs increasing resources to sustain itself, and the growth of affluent societies that consume and waste a very large proportion of resources and energy. The increasing extraction of resources is at the cost of our natural ecosystems, leading to a derailing of their important functions. We all use a variety of resources in our daily lives. If traced back to their source, we find that the resources were originally obtained from nature and natural ecosystems. Our insensitivity to using resources carefully has produced societies that nature can no longer sustain. If we think before wasting resources such as water, reuse and recycle paper, use less non-biodegradable material, then all this can cumulatively help conserve our natural resources.

Summary

- Ecosystems represent the living community of plants and animals in any area along with the non-living components of the environment such as soil, air and water.
- The structural aspects of ecosystems include *producers* (plants which manufacture food), *consumers* (plants, animals and invertebrates that live on producers) and *decomposers* (worms, insects, bacteria and fungi which break down organic material into smaller particles).
- Every ecosystem has several interrelated mechanisms that cycle through the biosphere: the water cycle, carbon cycle, nitrogen cycle, phosphorus cycle, sulphur cycle and the energy cycle. Human activities play a significant role in altering these cycles.

- Carnivores feed on herbivores which in turn feed on plants. At every stage of this food chain, energy is transferred and lost from one living organism to another.
- All the interlinked food chains together form a food web. Loss or extinction of species implies that a food web has broken down.
- Terrestrial ecosystems in their natural state are found in different types of forests, grasslands, semi-arid areas, deserts and sea-coasts. Over thousands of years, these ecosystems have been modified for human use and converted into intensively irrigated agricultural ecosystems and urban industrial centres.
- Aquatic ecosystems comprise the marine environments of the seas and freshwater systems in lakes, rivers, ponds and wetlands.
- Land use changes, habitat loss, disruption of environmental cycles and population pressure are some of the driving forces of ecosystem degradation.
- Ecosystems provide a range of goods and services essential to human life. Therefore, it is crucial that we protect and conserve our natural ecosystems and its resources.

Questions

1. Define an ecosystem.
2. Describe at least five ecosystem goods and services that humans benefit from.
3. Name all the cycles that constitute the proper functioning of an ecosystem.
4. Describe the water cycle.
5. Describe any two forest ecosystems in India. What are the current threats to forest ecosystems and how can they be conserved?
6. Name the types of grasslands in India and two animal species found in these grasslands.
7. Describe any two aquatic ecosystems in terms of their structure and function.
8. What are the main threats to aquatic ecosystems, and how can we protect them?

Unit 4

Biodiversity जैवविविधता

Let's understand

- About genetic, species and ecosystem diversity
- The biogeographic classification of India
- The value of biodiversity
- About biodiversity at the global, national and local levels
- Which the hotspots of biodiversity are
- What the threats to biodiversity are—habitat loss, poaching, human–wildlife conflicts
- The endangered and endemic species of India
- About in situ and ex situ conservation of biodiversity

4.1 INTRODUCTION

The great variety of life on earth has provided for the needs of human beings over thousands of years. This diversity of living creatures forms a support system used by each civilisation for its growth and development. Those that used this bounty of nature carefully and sustainably survived, while those that overused or misused it disintegrated.

Science has attempted to classify and categorise variations in nature for over a century. This has led to an understanding of its organisation into communities of plants and animals. This information has helped us utilise the earth's biological wealth for the benefit of humanity and has been integral to the process of development. This includes better health-care, better crops and the use of these life forms as raw materials for industrial growth, which has led to a higher standard of living for the developed world. However, this has also produced the modern consumerist society, which adversely affects the diversity of biological resources upon which it is based. The diversity of life on earth is so great that if we use it sustainably we can go on developing new products for many generations. This can only happen if we manage biodiversity as a precious resource and prevent the extinction of species.

Definition

Biological diversity or biodiversity is that part of nature which includes the differences in genes among the individuals of a species; the variety and richness of all the plant and animal species at different scales in space—locally, in a region, in the country and the world; and the types of ecosystems, both terrestrial and aquatic, within a defined area.

What is biodiversity?

Biological diversity deals with the degree of nature's variety in the biosphere. This variety can be observed at three levels—the genetic variability within a species; the variety of species within a community; and the organisation of species in an area into distinctive plant and animal communities.

आनुवंशिक

4.1.1 Genetic Diversity

Each member of any animal or plant species differs widely from other individuals in its genetic makeup, owing to the large number of combinations possible in the genes that give every individual its specific characteristics. For example, each human being is different from another. This genetic variability is essential for a healthy breeding population of a species. If the number of breeding individuals is reduced, the dissimilarity of genetic makeup is reduced and in-breeding occurs. This leads to genetic anomalies and eventually to the extinction of that particular species. The diversity in wild species forms the 'gene pool' from which our crops and domestic animals have been developed over thousands of years. Today, the variety of nature's bounty is being further exploited by using wild relatives to create new varieties of more productive, disease-resistant crops and to breed superior domestic animals. Modern biotechnology also manipulates genes to develop better types of medicines and a variety of industrial products.

4.1.2 Species Diversity

The number of species of plants and animals present in a region constitutes its species diversity. This diversity is seen both in natural ecosystems and in agricultural ecosystems. Some areas are richer in species than others. For example, natural undisturbed tropical forests have much greater richness of species than monoculture plantations developed by the Forest Department for timber production. A natural forest ecosystem provides a large number of non-timber forest products (NTFPs) that local people depend on, such as fruit, fuelwood, fodder, fibre, gum, resin and medicines. Timber plantations do not provide the large variety of goods essential for local consumption. In the long term, the economic sustainable returns from NTFPs is said to be greater than the returns from felling a forest for its timber. Thus, the commercial value of a natural forest, with all its species richness, is much greater than a plantation. Modern intensive agricultural ecosystems have a relatively lower diversity of crops than traditional agro-pastoral farming systems, where multiple crops were planted.

At present, conservation scientists have been able to identify and categorise about 1.8 million species on earth. However, this is only a fraction of what really exists. Many new species are being identified, especially among flowering plants and insects. Areas that are rich in species diversity are called *hotspots* of diversity. India is among the world's 15 nations that are exceptionally rich in species diversity.

4.1.3 Ecosystem Diversity

A large variety of ecosystems exist on earth, each with their own complement of distinctive interlinked species based on differences in the habitat. Ecosystem diversity can be described for a specific geographical region or a political entity such as a country, a state or a *taluka*. Distinctive ecosystems include landscapes like forests, grasslands, deserts and mountains as well as aquatic ecosystems like rivers, lakes and seas. Each region also has areas modified by humans such as farmland or grazing pastures.

An ecosystem is referred to as 'natural' when it is relatively undisturbed by human activities or 'modified' when it is converted to other types of uses, such as farmland or urban areas. Ecosystems are most natural in the wilderness. If natural ecosystems are overused or misused, their productivity eventually decreases and they are then said to be degraded.

Evolution and the Genesis of Biodiversity

The origins of life on earth some three-and-a-half billion years ago are obscure. Life was probably initiated as a product of organic reactions in the earth's primordial seas. Alternative possibilities such as life beginning in muddy ooze, or of life having been seeded from outer space have also been suggested. Once life took hold on the planet, it began to gradually diversify. Unicellular unspecialised forms gradually evolved into complex multicellular plants and animals. Evolution is related to the ability of living organisms to adapt to changes in their environment. Thus, the abiotic changes in nature, such as climatic and atmospheric upheavals, repeated glaciations, continental drift and the formation of geographical barriers, segregated different communities of plants and animals and gradually led to the formation of new species over millions of years.

Most species appear to have a life span extending over several million years. Their adaptability to gradual changes in their habitat and interactions with newly-formed species produced groups of interlinked organisms that continue to evolve together. Food chains, prey–predator relationships, parasitism (complete dependence on another species) and symbiosis (a partnership beneficial to both species) are some important examples. The behavioural patterns of the different species comprising a community of species link them to each other through their breeding biology, feeding patterns and migrations. As ancient species became extinct due to geological upheavals, they left behind empty 'niches' in the habitat that stimulated existing species to fill them through the formation of new species. The earth's ancient history has seen periods of mega-extinctions, which have been followed by periods of formation of new species. Though these repeatedly led to a drastic reduction in the number of species, the diversity of life recuperated each time by gradually increasing the number of species existing on earth. This, however, took millions of years, as evolution is a very slow process. Thus, when humans appeared on the scene about 2 million years ago, the earth was richer in species than ever before. During the recent past, however, extinctions caused by the activities of modern humans have begun to take place at an unprecedented rate. The earth is now losing species at a faster rate than ever before.

The diversity of life at all three organisational levels – genetic, species and ecosystem – is now being rapidly modified by modern humans. This will result in great loss to future generations.

4.2 BIOGEOGRAPHIC CLASSIFICATION OF INDIA

India can be conveniently divided into ten major regions, based on the geography, climate, pattern of vegetation and the communities of mammals, birds, reptiles, amphibians, insects

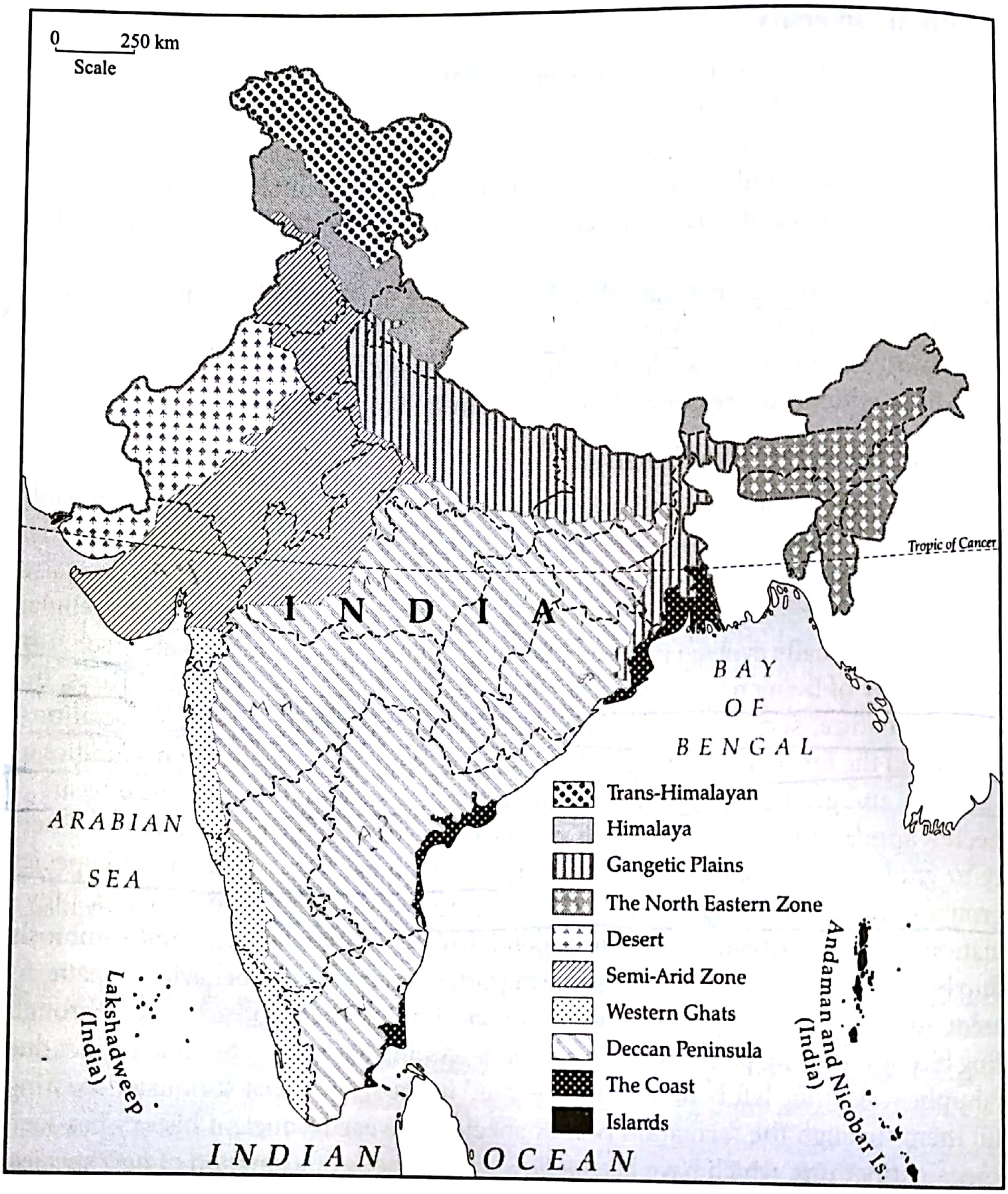


Fig. 4.1 Biogeographic classification of India

and other invertebrates that live in them. Each of these regions contains a variety of ecosysten such as forests, grasslands, lakes, rivers, wetlands, mountains and hills which have specif plant and animal species.

India's Biogeographic Zones

(i) The cold, mountainous, snow-covered trans-Himalayan region of Ladakh
(ii) The Himalayan ranges and valleys of Kashmir, Himachal Pradesh, Uttarakhand, Assa and other Northeastern states
(iii) The *Terai*, the lowland where the Himalayan rivers flow into the plains

(iv) The Gangetic and Brahmaputra plains
(v) The Thar desert of Rajasthan
(vi) The semi-arid grassland region of the Deccan plateau, Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu
(vii) The Northeastern states of India
(viii) The Western ghats in Maharashtra, Karnataka and Kerala
(ix) The Andaman and Nicobar islands
(x) The long western and eastern coastal belts with sandy beaches, forests and mangroves

4.3 VALUE OF BIODIVERSITY

Biodiversity provides a variety of environmental services from its species and ecosystems that are essential at the global, regional and local levels. The production of oxygen, reduction of carbon dioxide, maintenance of the water cycle and protection of the soil are some important services.

Biological diversity is also essential for preserving ecological processes, such as fixing and recycling of nutrients, soil formation, circulation and cleansing of air and water, global life support (plants absorb CO_2 and give out O_2), maintaining the water balance within ecosystems, watershed protection, maintaining stream and river flows throughout the year, erosion control and local flood reduction.

Food, clothing, housing, energy and medicines are all resources that are directly or indirectly linked to the biological variety present in the biosphere. This is most obvious in the case of tribal communities who directly gather resources from the forest or fisherfolk who catch fish in marine or freshwater ecosystems. For others, such as agricultural communities, biodiversity is used to grow crops to suit the environment. Urban communities generally use the greatest amount of goods and services, which are all indirectly drawn from natural ecosystems.

It has become obvious that the preservation of biological resources is essential for the well-being and the long-term survival of humans. This diversity of living organisms, which is present in the wilderness as well as in crops and livestock, plays a major role in human development. The preservation of biodiversity is, therefore, integral to any strategy that aims at improving the quality of human life.

4.3.1 Consumptive Use Value

A straightforward example is the direct utilisation of timber, food, fuelwood and fodder by local communities.

The biodiversity contained in the ecosystem provides forest dwellers with their daily needs, food, building material, fodder, medicines and a variety of other products. They know the qualities and different uses of wood from different species of trees and collect a large number of local fruits, roots and plant material that they use as food, construction material and medicines. Fisherfolk are completely dependent on fish and know where and how to catch fish and other edible aquatic animals and plants.

Man and the Web of Life

The biodiversity of a region influences every aspect of the lives of the people who inhabit it. Their living space and livelihoods depend on the type of ecosystem. Even people living in urban areas are dependent on the ecological services provided by the wilderness in the PAs. We frequently do not see this in everyday life, as it is not necessarily obvious. However, it is linked with every service that nature provides. The quality of water we drink and use, the air we breathe, the soil on which our food grows are all influenced by a wide variety of living organisms, both plant and animal, and the ecosystem with which each species is linked with in nature.

While it is well-known that plant life removes carbon dioxide and releases the oxygen that we require to breathe, it is less obvious that fungi, small soil invertebrates and even microbes are essential for plants to grow. Links such as that of a natural forest which maintains water in the river after the monsoon, or of ants playing a crucial role in transferring nutrients to the soil, are to be appreciated in order to understand how we are completely dependent on the living 'web of life' on earth.

The wilderness is an outcome of a long evolutionary process that has created an unimaginably large diversity of living species and the various ecosystems on earth in which all creatures live. This includes humans as well. Think about this and we cannot but want to protect our earth's unique biodiversity!

4.3.2 Productive Use Value

This category comprises marketable goods. The biotechnologist uses bio-rich areas to prospect and search for potential genetic properties in plants or animals that can be used to develop better varieties of crops for use in farming and plantation programmes or to develop better livestock. To the pharmacist, biological diversity is the raw material from which new drugs can be identified from plant or animal products. To industrialists, biodiversity is a rich storehouse from which to develop new products. For the agricultural scientist, the biodiversity in the wild relatives of crop plants is the basis for developing better crops.

Genetic diversity enables scientists and farmers to selectively develop better crops and domestic animals through careful breeding programs. Earlier, this was done by selecting or pollinating crops artificially to obtain a more productive or disease-resistant strain. Today, it is increasingly being done by genetic engineering—selecting genes from one plant and introducing them into another. New crop varieties (cultivars) are being developed using the genetic material found in wild relatives of crop plants through biotechnology.

Even today, new species of plants and animals are being constantly discovered in the wild. These wild species are the building blocks for the betterment of human life and their loss is a great economic loss. Among the known species, only a tiny fraction has been investigated for their value in terms of food or their medicinal or industrial potential.

A variety of industries such as pharmaceuticals, are highly dependent on identifying compounds of great economic value from the wide variety of wild species of plants located in undisturbed natural forests. This is called *biological prospecting*.

Table 4.1 Commonly used modern drugs derived from plant sources

Drug	Plant source	Use
Atropine	Belladonna	Anticholinergic; reduces intestinal pain in diarrhoea
Bromelain	Pineapple	Controls tissue inflammation due to infection
Caffeine	Tea, coffee	Stimulant of the central nervous system
Camphor	Camphor tree	Rubefacient; increases local blood supply
Cocaine	Cocoa	Analgesic and local anesthetic; reduces and prevents pain during surgery
Codeine	Opium poppy	Analgesic; reduces pain
Morphine	Opium poppy	Analgesic; controls pain
Colchicine	Autumn crocus	Anti-cancer agent
Digitoxin	Common foxglove	Cardiac stimulant used in heart diseases
Diosgenin	Wild yams	Source of female contraceptive; prevents pregnancy
L-Dopa	Velvet bean	Controls Parkinson's disease, which leads to jerky movements of the hands
Ergotamine	Smut-of-rye or ergot	Control of hemorrhage and migraine headaches
Glaziovine	*Ocotea glaziovii*	Antidepressant
Gossypol	Cotton	Male contraceptive
Indicine N-oxide	*Heliotropium indicum*	Anti-cancer agent
Menthol	Mint	Rubefacient; increases local blood supply and reduces pain on local application
Monocrotaline	*Cotolaria sessiliflora*	Anti-cancer agent
Papain	Papaya	Dissolves excess protein and mucus, during digestion
Penicillin	*Penicillium* fungi	General antibiotic, kills bacteria and controls infection by various microorganisms
Quinine	Yellow cinchona	Antimalarial
Reserpine	Indian snakeroot	Reduces high blood pressure
Scopolamine	Thorn apple	Sedative
Taxol	Pacific yew	Anti-cancer (ovarian)
Vinblastine	Rosy periwinkle	Anti-cancer agent; controls cancer in children
Vincristine	*Vinca rosea* (*Sadaphali*)	Anti-cancer agent; controls cancer in children

Source: E O Wilson, *The Diversity of Life*, Norton Paperback, In association with Harvard University Press, 1993

4.3.3 Social Values

Biodiversity has, to a great extent, been preserved by traditional societies that valued it as a resource and appreciated that its depletion would be a great loss to their society. Thus, apart from the local use or sale of products of biodiversity, the social aspect must also be considered. For example, many plants and animals are considered sacred in India and are worshipped. For example, *Tulsi*, *peepal*, cow, snake and others.

4.3.4 Ethical and Moral Values

Ethical values related to biodiversity conservation are based on the importance of protecting all forms of life. Most religious and secular creeds believe that all forms of life have the right to exist on earth. Humans are only a small part of the earth's great diversity of species. We do not know if life as we know it exists anywhere else in the universe. Do we have the right to destroy life forms or do we have a duty to protect them?

Apart from the economic importance of conserving biodiversity, there are several cultural, moral and ethical values associated with the sanctity of all forms of life. The Indian civilisation has, over several generations, preserved nature through local traditions. This has been an important part of the ancient philosophy of many of our cultures. We have in our country a large number of sacred groves or '*devrais*' preserved by tribal people in several states. These sacred groves around ancient sacred sites and temples act as gene banks for wild plants.

4.3.5 Aesthetic Value

The appreciation of the presence of biodiversity for its inherent value and beauty, as well as for the contribution it makes to our knowledge – our aesthetics, imagination and creativity – is another reason to preserve it. Quite apart from killing wildlife for food, it is important as a tourist attraction. Biodiversity is a beautiful and wonderful aspect of nature. Sit in a forest and listen to the birds. Watch a spider weave its complex web. Observe a fish feeding. It is magnificent and fascinating.

In India, particularly, history and culture is replete with plant and animal imagery. Symbols from wild species such as the lion of Hinduism, the elephant of Buddhism and deities such as Lord Ganesh and the vehicles of several deities that are animals have been venerated for thousands of years. The sage Valmiki begins his epic story with a couplet on the unfortunate killing of a crane by a hunter. The holy basil or *Tulsi* has been grown in the courtyards of households for centuries.

4.3.6 Option Value

Keeping future possibilities open for their use is called the option value. It is impossible to predict which of our species or traditional varieties of crops and domestic animals will be of greatest use in the future. To continue to improve cultivars and domestic livestock, we need to return to wild relatives of crop plants and animals. Thus, the preservation of biodiversity must also include traditionally used strains already in existence in crops and domestic animals.

4.4 BIODIVERSITY AT GLOBAL, NATIONAL AND LOCAL LEVELS

There are at present 1.8 million known species that have been documented by scientists in the world. However, they have estimated that the number of species of plants and animals on earth could vary from 1.5 to 20 billion! This means that the majority of species are yet to be discovered!

Most of the world's bio-rich nations are in the south; in other words, they are the developing nations. In contrast, the majority of the countries capable of exploiting biodiversity are the northern nations, in the economically developed world. These nations, however, have lower levels of biodiversity. Thus, after centuries of exploitation, the developed world has come to realise that biodiversity must be considered as a global resource. However, if biodiversity should form a 'common property resource' to be shared by all nations, there is no reason to exclude oil or uranium or even intellectual and technological expertise as global assets. India's sovereignty over its biological diversity cannot be compromised without a revolutionary change in world thinking about sharing of all types of natural resources.

Some of the countries with higher biodiversities than India are located in South America, such as Brazil and Southeast Asian countries such as Malaysia and Indonesia. The species found in these countries, however, are different from our own. This makes it imperative to preserve our own biodiversity as a major economic resource. While few of the other 'mega-diversity nations' have developed the technology to exploit their species for biotechnology and genetic engineering, India is capable of doing so.

Throughout the world, the value of biologically-rich natural areas is now being increasingly appreciated as being of unimaginable value. International agreements, like the World Heritage Convention, attempt to protect and support such areas. ① India is a signatory to the convention and has included several protected areas as world heritage sites. These include Manas on the border between Bhutan and India, Kaziranga in Assam, Bharatpur in UP, Nandadevi in the Himalayas and the Sunderbans in the Ganges delta in West Bengal.

② India has also signed the Convention in the Trade of Endangered Species (CITES), which is intended to reduce the utilisation of endangered plants and animals by controlling trade in their products and in the pet trade.

③ The Union Ministry of Environment and Forests (MoEF), the nodal agency for implementing provisions of CBD in India, developed a strategy for biodiversity conservation at the macro-level in 1999 and got the Biological Diversity Act enacted in 2002 followed by the rules thereunder in 2004. Considering the need to develop and implement a suitable national action plan for promoting biodiversity conservation, sustainable use of its components and equitable sharing of benefits arising from such use the National Biodiversity Action Plan was formulated in 2007.

4.5 INDIA AS A MEGA-DIVERSITY NATION

Geological events in the landmass of India have provided conditions for high levels of biological diversity. A split in the single giant continent around 70 million years ago led to the formation of northern and southern continents, with India as part of Gondwanaland—the southern landmass, together with Africa, Australia and the Antarctic. Later, tectonic movements shifted India northward across the equator to join the Northern Eurasian continent. As the intervening shallow Tethys sea dried up, plants and animals that had evolved both in Europe and in the Far East migrated into India before the Himalayas had formed. A final influx came from Africa with Ethiopian species, which were adapted to the savannas and semi-arid regions. Thus, India's special geographical position or 'niche' between three distinctive centres of biological evolution and radiation of species is responsible for our rich and varied biodiversity.

Among the bio-rich nations, India is in the top 10 or 15 countries for its great variety of plants and animals, many of which are not found elsewhere. India has 350 different mammals (rated the eighth highest in the world), 1,200 species of birds (eighth in the world), 453 species of reptiles (fifth in the world) and 45,000 plant species, most of which are angiosperms (fifteenth in the world). These include especially high species diversity of ferns (1022 species) and orchids (1082 species). India has 50,000 known species of insects, including 13,000 butterflies and moths. It is estimated that the number of unknown species could be several times higher.

Table 4.2 India's biodiversity status

Species	India's world ranking	Number of species in India
Mammals	8	350
Birds	8	1200
Reptiles	5	453
Amphibians	15	182
Angiosperms	15–20	14,500

It is estimated that 18% of Indian plants are endemic to the country and found nowhere else. Among the plant species, the flowering plants have a much higher degree of endemism, a third of these are not found elsewhere in the world. Among amphibians found in India, 62% are unique to this country. Of the 153 species of lizards recorded, 50% are endemic. High endemism has also been recorded for various groups of insects, marine worms, centipedes, mayflies and freshwater sponges.

Apart from the high biodiversity in Indian wild plants and animals, there is also a great diversity of cultivated crops and breeds of domestic livestock. This is a result of several thousand years during which civilisations have grown and flourished in the Indian subcontinent. The traditional cultivars included 30,000 to 50,000 varieties of rice and a number of cereals, vegetables and fruit. The highest diversity of cultivars is concentrated in the high-rainfall areas of the Western ghats, Eastern ghats, Northern Himalayas and the Northeastern hills.

Gene banks have collected over 34,000 cereals and 22,000 pulses grown in India. India has 27 indigenous breeds of cattle, 40 breeds of sheep, 22 breeds of goats and 8 breeds of buffaloes. Many of these today have died out or are dying out due to our misguided adoption of all things foreign—Jerseys and Holsteins have largely replaced Indian cattle like the Brahma bull, high-yielding cultivars have eaten away into centuries-old landraces of crops, cash crops have replaced food crops, eucalyptus and wattle plantations have replaced the mixed *shola* forests. The Indian landscape is slowly beginning to lose its individuality and resemble any other scenery in the world.

4.6 HOTSPOTS OF BIODIVERSITY

The earth's biodiversity is distributed in specific ecological regions. There are over a thousand major eco-regions in the world. Of these, 200 are said to be the richest, rarest and most distinctive natural areas. These areas are referred to as the 'Global 200'.

It has been estimated that 50,000 endemic plants, which comprise 20% of global plant life, probably occur in only 18 hotspots in the world. Countries which have a relatively large proportion of these biodiversity hotspots are referred to as mega-diversity nations.

The rate at which the extinction of species is taking place throughout our country remains obscure. It is likely to be extremely high, as our wilderness areas are shrinking rapidly. Our globally-accepted national hotspotswhich are included in the world's most bio-rich areas are in the forests of the Northeast and the Western ghats. The Andaman and Nicobar islands are extremely rich in species and many subspecies of different animals and birds have evolved. Among the endemic species, that is, those species found only in India, a large proportion are

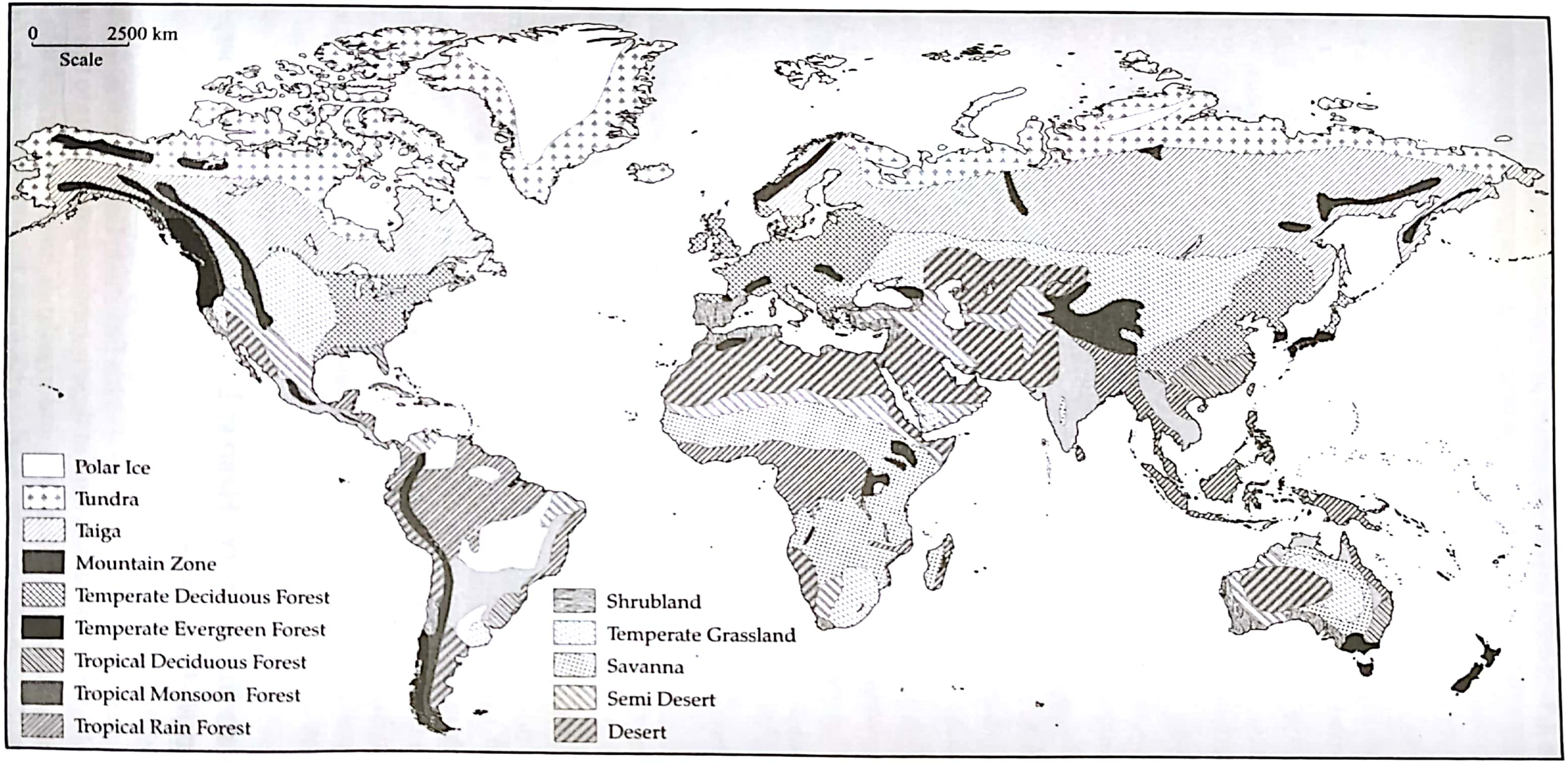


Fig. 4.2 Biogeographical zone of the world

Table 4.3 Global species diversity

Group	Number of described species
Bacteria and blue-green algae	4,760
Fungi	46,983
Algae	26,900
Bryophytes (mosses and liverworts)	17,000 (WCMC, 1988)
Gymnosperms (conifers)	750 (Reven et al., 1986)
Angiosperms (Flowering plants)	250,000 (Reven et al., 1986)
Protozoans	30,800
Sponges	5,000
Corals and jellyfish	9,000
Roundworms and earthworms	24,000
Crustaceans	38,000
Insects	751,000
Other arthropods and minor invertebrates	132,461
Molluscs	50,000
Starfish	6,100
Fishes (teleosts)	19,056
Amphibians	4,184
Reptiles	6,300
Birds	9,198 (Clements, 1981)
Mammals	4,170 (Honacki et al., 1982)
Total	1,435,662 species

Source: Conserving the World's Biological Diversity, WRI, IUCN, CI, WWF-US, World Bank

concentrated in these three areas. The Andaman and Nicobar islands alone have as many as 2200 species of flowering plants and 120 species of ferns. Out of 135 genera of land mammals in India, 85 (63%) are found in the Northeast. The Northeastern states also have 1,500 endemic plant species. A major proportion of amphibian and reptile species, especially snakes, are concentrated in the Western ghats, which is also a habitat for 1,500 endemic plant species.

Coral reefs in Indian waters surround the Andaman and Nicobar islands, the Lakshadweep islands and the gulf areas of Gujarat and Tamil Nadu. They are nearly as rich in species as tropical evergreen forests!

4.7 THREATS TO BIODIVERSITY: HABITAT LOSS, POACHING OF WILDLIFE, HUMAN–WILDLIFE CONFLICTS

Habitat Loss

Man has begun to overuse or misuse most of these natural ecosystems. Due to this unsustainable use of resources, once-productive forests and grasslands have been turned into deserts and wastelands have increased all over the world. Mangroves have been cleared for fuelwood and prawn farming, which has led to a decrease in the habitat essential for the breeding of marine fish. Wetlands have been drained to increase agricultural land. These changes have grave economic implications in the longer term.

The current destruction of the remaining large areas of wilderness habitats, especially in the diverse tropical forests and coral reefs, is the most palpable threat worldwide to biodiversity. Scientists have estimated that human activities are likely to eliminate approximately 10 million species by the year 2050.

As mentioned earlier, there are about 1.8 million species of plants and animals known to science in the world at present. The number of species, however, is likely to be greater by a factor of at least 10. Plants and insects as well as other forms of life not known till date are continually being identified in the world's hotspots of diversity. Unfortunately, at the present rate of extinction, about 25% of the worlds' species will undergo extinction fairly rapidly. This may occur at the rate of 10,000–20,000 species per year, at a rate 1000–10,0000 times faster than the expected natural rate! Human actions could well exterminate 25% of the world's species within the next twenty or thirty years. Much of this mega-extinction is related to human population growth, industrialisation and changes in land use patterns. A major part of these extinctions will, of course, occur in bio-rich areas such as tropical forests, wetlands and coral reefs. The loss of wild habitats, due to rapid human population growth and short-term economic development, is the contributor to the rapid global destruction of biodiversity.

CASE STUDY I

Project Tiger

Project Tiger was launched by the Government of India with the support of WWF-International in 1973 and was the first such initiative aimed at protecting this key species and all its habitats. Project Tiger was initiated in nine tiger reserves in different ecosystems of the country, covering an area of 16,339 sq. km. By 2001, the number of tiger reserves increased to 27, covering an area of 37,761 sq. km. The tiger count climbed from 268 in 1972 in the 9 tiger reserves, to around 1500 in 1997 in the 23 tiger reserves. Project Tiger recognised the fact that tigers cannot be protected in isolation and that to protect the tiger, its habitat needs to be protected. However, Project Tiger's success was damaged by a new threat of poaching. Tiger numbers again began to decline. The sudden disappearance of the tigers from the Sariska wildlife reserve exposed a whole network of illegal poachers taking tigers out of India for Chinese markets.

Tiger Task Force: In 2005, the Prime Minister of India took direct action to protect tigers by setting up the Tiger Task Force. The Task Force presents an action agenda to manage tiger conservation the Indian way, where forests are not only considered as wilderness but also the homes of people.

Island flora and fauna, which have high endemism in small isolated areas surrounded by the sea on all sides, have so far been most seriously affected by human activity. This has already led to the extinction of many island plants and animals (the Dodo in Madagascar is a well known example). Habitat loss also results from the introduction of species from one area into another by humans, disturbing the balance in existing communities. In the process, the purposely or accidentally introduced organisms (some notorious examples being *Eupatorium*, *Lantana*, Water

Hyacinth, 'Congress grass' or *Parthenium*) have led to the extinction of many local species and have also adversely affected human health.

Human–Wildlife Conflicts

The loss of species occurs due to the destruction of natural ecosystems, either for conversion to agriculture or industry, or by over-extraction of their resources, or through pollution of air, water and soil.

In India, forests and grasslands are continuously being converted to agricultural land. Encroachments have been repeatedly legalised. Similarly, our natural wetland systems have been drained to establish croplands resulting in loss of aquatic species. Grasslands that were once sustainably used by a relatively smaller number of human beings and their cattle are either changed to other forms of use or degraded by over-grazing.

Our natural forests are being deforested for timber and replanted using teak, sal or other single species for their timber value. Such monoculture plantations do not support the same biological diversity as a multistoried natural forest, which has a closed canopy and a rich undergrowth of vegetation; nor do they nourish the soil.

When excessive firewood is collected from the forest by lopping the branches of trees, the forest canopy is opened up and this alters the local biodiversity. Foraging cattle retard the regeneration of the forest, as young seedlings are constantly trampled.

CASE STUDY 2

Kokkare Bellur, Karnataka: Coexistence (humans and wildlife)

The pelican, which is an endangered species, breeds in large numbers at Kokkare Bellur, which is one of the ten known breeding sites in India. Kokkare Bellur is a village in Karnataka in Southern India. In December every year, hundreds of spot-billed pelicans, painted storks, ibis and other birds migrate to this area to establish breeding colonies on the tall tamarind trees in the centre of the village. The local people have protected the birds, believing that they bring good luck with relation to rain and crops. The villagers collect a rich supply of the natural fertiliser that collects below the nests, the *guano*. The droppings of these fish-eating birds are rich in nitrates.

The owners of the trees inhabited by the birds dig deep pits under the trees, into which the guano falls. Silt from nearby lakes and ponds are mixed with the guano, which is used in their fields and sold as fertiliser. They have now planted trees around their homes to encourage nesting.

Over-Exploitation

The ever-increasing human population pressing on the fringes of our PAs degrades forest ecosystems, and the not-so-subtle daily encroachments gradually decrease the buffer zones and the forested areas. A prime example is the Gir National Park, the last bastion of the Asiatic lion—a metre-gauge railway runs through the park, a state expressway, and three temples.

This is a major factor to consider in evaluating the quality of the ecosystem. Repeated fires started by local grazers to increase the growth of grass ultimately reduce regeneration and lower the diversity of plant species. Without alternate sources of fodder, this pressure cannot be decreased.

Exotic Species

Another factor that disrupts forest biodiversity is the introduction of exotic weeds, which are not a part of the natural vegetation. Some common examples in India are lantana bushes, *Eupatorium* shrubs and congress grass. These have been imported into the country from abroad and have invaded large tracts of our natural forests. These weeds spread at the expense of the diverse range of indigenous undergrowth species. The impact on the diversity of insect, bird and other wildlife species, though not adequately studied, is quite obvious.

In our country a variety of traditional farming techniques have evolved over several centuries—slash-and-burn cultivation in the Himalayas, and *rab*, lopping off tree branches to act as a wood-ash fertiliser in the Western ghats, are two such systems. When the human population in these areas was low, these were sustainable methods of agriculture. Unfortunately, these areas now have a large number of people who subsist largely on forest agriculture. These methods are now unsustainable and are leading to loss of forest biodiversity.

The over-harvesting of fish, especially using large trawling boats, is leading to serious depletion of fish stocks. Marine turtles, which are inadvertently caught in fishing nets, are being massacred off the coast of Orissa. The rare whale shark, a highly-endangered species, is being killed off the coast of Gujarat.

Poaching

Specific threats to certain animals are related to large economic benefits. The skin and bones of tigers, ivory of elephants, horns of rhinos and perfume of the musk deer are extensively used abroad. Bears are killed for their gall bladders. Corals and shells are also collected for export or sold on the beaches of Chennai, Kanyakumari and the Andaman and Nicobar islands. Tortoises, exotic birds and other small animals are packed into tiny containers and smuggled abroad for pet trade. A variety of wild plants with real or sometimes dubious medicinal values are being over-harvested. The commonly collected plants include Rauwolfia, *Nux vomica*, Datura and others. The garden plants collected for illegal trade include orchids, ferns and mosses.

The rights of species

We do not see all the varied functions that biodiversity plays in our lives because they are not obvious. We rarely see how they control our environment unless we study nature closely, over a period of time. We tend to overlook nature's inter-relationships and take short-term actions that can have a serious impact on biodiversity and its habitats. Humans do not have a right to do this. We only share this planet with millions of other species that also have a right to survive. It is morally wrong to allow our actions to lead to the extinction of species.

4.8 ENDANGERED AND ENDEMIC SPECIES OF INDIA

To appreciate the endemic and endangered species of India, it is important to understand the wide variety of plant and animal species found in the country. Of the well-known species, several are endangered by human activity. The endangered species are categorised as *vulnerable, rare, indeterminate* and *threatened*. Other species are found only in India and are thus endemic or restricted to our country. Some of these may have very localised distribution and are considered highly endemic.

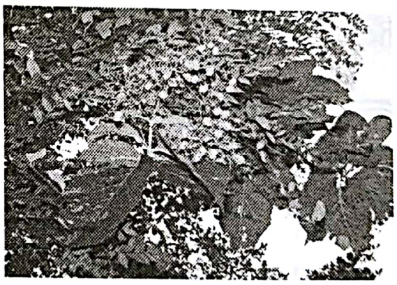
Several plant and animal species in the country are now found in only one or a few PAs. Among the important endangered animals are charismatic species such as the tiger, elephant, and rhinocerous. The less well-known major mammals, restricted to a single area, include the Indian wild ass, *Hangul* or Kashmir stag, golden *langur*, pygmy hog and a host of others. There are also endangered bird species, like the Siberian crane, the great Indian bustard, the florican and several birds of prey. In the recent past, vultures, which were common a decade ago, have suddenly disappeared and are now highly threatened. Equally threatened are several species of reptiles and amphibians. Many invertebrates are also threatened, including a large number of species that inhabit our coral reefs.

Many plant species are now increasingly threatened due to changes in their habitat induced by human activity. Apart from the major trees, shrubs and climbers that are extremely habitat-specific and thus endangered, thousands of small herbs are also greatly threatened by habitat loss. Several orchids are yet another group under threat. Many plants are threatened due to over-harvesting as ingredients in medicinal products or cosmetics.

To protect the endangered species, India has created the Wildlife Protection Act. This includes lists of plants and animals categorised according to the threat to their survival.

We know so little about the species diversity of our country. Most of us are only aware of the plight of a few glamourous large mammals, but we need to appreciate the threat to the lesser known species of plants and animals. We need to find ways to support the conservation of India's incredible wildlife for its future generations.

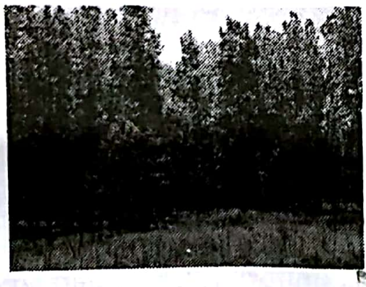
4.8.1 Common Plant Species


ERACH BHARUCHA

Teak

Teak: This tree is from the southwest of peninsular India. It is a common tree in deciduous forests, and yields the much-sought-after timber used for making furniture. During the early British period, it was cut down from many forest tracts to build ships. As stocks were diminishing, the British selected areas which they called Reserved Forests where teak was planted for the Government's use. Teak is grown extensively by the Forest Department and is a highly priced wood.

The teak tree is identified by its large leaves, which grow to more than 40–50 cm long and 20 cm wide; it has tiny flowers and fruit. In the winter, the trees shed all their leaves. In the growing season, which begins in April and extends through the monsoon, teak forests are bright green and shady. Most natural teak forests have various other species of plants and a large number of wild animals. Some teak forests that have exceptional populations of wildlife have been declared as PAs and included in our national parks and wildlife sanctuaries.


ERACH BHARUCHA

Sal

Sal: This is a common species found in several types of forests of the Northeastern region of India, extending into

Madhya Pradesh and Orissa. It has bright green foliage and its canopy remains green almost throughout the year. Sal wood is hard and durable. Sal trees yield a large number of seeds used in making cosmetics. Sal forests are rich in wild mammals, birds, reptiles and insect life. Several areas are included in our network of national parks and sanctuaries.

Mango: This has become one of our most popular horticultural species, with different varieties being grown all over the country. The wild mango tree has small tangy fruit and a big seed, in comparison to the large pulpy fruit used in horticulture. The mango tree is an evergreen species and has small flowers pollinated by insects. In the forest, fruit-dependent animals such as monkeys, squirrels, fruit bats and birds relish its ripe fruit.

Mango

Ficus

Ficus: The *peepal*, banyan and many other ficus species comprise this. They are all ecologically of great importance as many different species of insects, birds and mammals feed on ficus berries. The flowers are inside the berries. They are pollinated by a specific wasp, which lays its eggs inside the berries on which the larvae feed and grow. The ficus trees bear berries throughout the year, thus supplying nutritious food to several animal species when the other trees have no fruit. Ficus species are thus known as 'keystone' species and support a major part of the food web in several ecosystems. Ficus trees, such as the *peepal* and banyan, are considered sacred and are protected in India.

Neem: This species is known as *Azadirachta indica*. It has been traditionally used in indigenous medicine. It has small yellow fruit; the leaves and fruit are bitter in taste. It is used extensively as an environmentally friendly insecticide. It grows extremely well in semi-arid regions and can be planted in afforestation programmes where the soil is poor and rainfall is low.

Neem

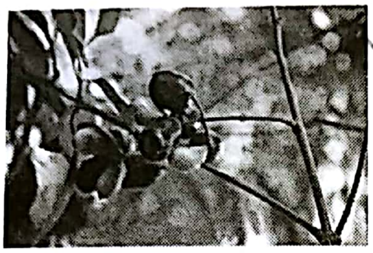
Tamarind: One of the best known Indian trees, it grows to a large size and is known to live for over 200 years. Its familiar fruit is a curved pod with sour pulp, containing a number of squarish seeds. The pulp in the fresh fruit is either green or red. As it ripens, it turns sticky and brown and separates from the skin. It is commonly cultivated as a shade tree and for its edible sour fruit, which contains high concentrations of vitamin C. It is used as a preservative and an additive in food to give a tangy flavour. It is valued for its timber as well as for fuelwood.

Babul: This is a thorny species that is characteristic of the semi-arid areas of Western India and the Deccan plateau. It grows sparsely in tracts of grassland and around farms, and is used for fodder and fuelwood. It remains green throughout the year even under the driest conditions and is browsed on by wild animals and cattle. It has small leaves and bright yellow flowers and small seed-pods with multiple seeds. Its main characteristic is its long, sharp, straight thorns, which prevent excessive browsing of its older branches.

Babul

Zizyphus: These are the small trees and shrubs typically found in the arid and semi-arid areas of India; *Z mauritiana* and *Z jujuba* are the most commonly found species. It is a favourite of frugivorous birds. The tree fruits extensively and these are eaten by a variety of birds and mammals. The popular fruit is commonly collected and sold in local markets.

Zizyphus



Jamun

Jamun: This tree is an evergreen species, which has a tasty purple fruit. It is a favourite with people and with many wild birds and mammals. It grows in many parts of India and has several varieties with fruits of different sizes.

Tendu: A mid-sized, deciduous tree, commonly found in dry deciduous forests throughout the Indian subcontinent. There are around 50 Indian species. Its bark exfoliates in large rectangular scales. It branches out profusely forming a dense crown. The leaves are elliptical and leathery and its young leaves are extensively used for making *bidis*. The fruit is brownish-yellow and astringent. Tendu-leaf collection necessitates burning the undergrowth and slashing the branches of the trees to get at the leaves. The resulting disturbance to wildlife is a serious issue in PAs.

Jackfruit: This tree is planted around many villages and has huge fruit growing directly from its branches. The fruit has a prickly skin. The unripe fruit is cooked like a vegetable. Once ripe, it turns into a sweet, sticky, golden-yellow fruit, which has a strong smell.

Flame of the forest (Butea monosperma): This tree grows in many parts of India. It has bright orange flowers when it is leafless, and is thus called the 'flame of the forest'. The flowers are full of nectar, which attract monkeys and many nectar-dependent birds.

Butea monosperma

Erythrina

Coral tree (Erythrina): A common deciduous tree that is leafless in February, when it gets bright scarlet flowers that are used for their nectar by many birds such as mynas, crows and sunbirds, which are its major pollinators. Its long black seed-pods contain several shiny brown seeds which germinate well. This tree can also be propagated by cutting and planting its young branches. It is a rapid grower and usually begins to flower in four or five years' time.

Amla (gooseberry): This deciduous medium-sized tree is known for its sour, greenish-yellow fruit, which are rich in vitamin C. It is used as a medicine, in pickles, and for dyeing and tanning. It is frequently referred to as the Indian olive, to which it has no similarity either in appearance or taste.

Amla

Dipterocarps: This group of trees grows in evergreen forests of the southern part of the Western ghats and in the

Northeast parts of India, in high rainfall areas. It grows to an enormous height and has a wide girth. The seed has a pair of wing-like structures which aid in wind dispersal.

Oak

Quercus (oak): It is a large tree and is an economically-important genus, which includes many trees known for their beautiful shape and their changing seasonal colours. There are 30–40 Indian species of this genus, found in the temperate areas throughout the Himalayas. The fruit is a large, hard, solitary characteristic nut (acorn). Oaks provide the finest hardwoods of great strength and durability and were once used for building ships and bridges. It is a famous wood for high-quality furniture. Some of its species are also excellent fodder plants.

Pine

Pine: There are five species of true pines found in India in the Himalayan region. The timber of these trees is frequently used in construction, carpentry and the paper industry. Pine resin is used to make turpentine, rosin, tar and pitch. Pine oils are obtained by distillation of the leaves and shoots. Pine leaves are thin and needle-like. The male and female spores are produced in woody cones, and the dispersal of pollen is aided by each grain having two wings.

Cycads: These plants are uncommon in India and have a palm-like appearance. Cycads along with conifers make up the gymnosperms. They are among the most primitive seed plants, and have remained virtually unchanged through the past 200 million years (since Jurassic times). There are five species found in India, mostly in high rainfall areas.

Coconut: This tall stately palm has a more or less straight trunk with circular markings, and is grows mostly in coastal plains. The base is surrounded by a mass of fine roots. It produces the familiar coconut, filled with liquid and a soft white edible, jelly-like material that hardens when the fruit ripens. It is a common ingredient of food in India, especially in the southern states. It is extensively cultivated along the coastal regions and islands of India. Most parts of the tree yield several useful products, such as broomsticks from its leaves and fibre from the husk of dried coconuts.

Orchids: This is the largest group of flowering plants in the world, with over 18,000 known species. Of these, 1500 species are found in India, making it one of the largest plant families in the country with a high concentration of a staggering 700 species in the Northeastern states. These plants are terrestrial or epiphytic herbs. The flowers show a range of bright colours and great variation in structure. In some species, one of the petals is distinct from the others and is called a lip or labellum; this colorful petal attracts pollinators. In India, a large number of orchid species are found in the Western ghats, the Northeast and the Andaman and Nicobar islands. Orchids are, however, seen in several ecological conditions except extremes such as very cold or very hot and dry ecosystems.

Orchid

Drosera: This is a small insectivorous plant, usually 5 or 6 cm in height, which has tiny hairs that secrete a sticky droplet of fluid on which insects get stuck. The leaf winds around the struggling insect, which is then slowly digested. The plant has pretty flowers. It grows in shallow, poor-quality soil. It is a rare plant and is found in small patches.

ERACH BHARUCHA

Drosera

Lotus: This is an aquatic floating plant with a large rhizome, which is rooted in mud. Its leaves are circular, flat and covered with a waxy coating, which protects it from water. The flower grows on an erect stalk with several petals ranging from pink violet to white. The fruit is a spongy cone with multiple round seeds. It is widely distributed in wetland habitats and shallow parts of lakes and marshy areas. The rhizome, stalks of the leaves and seeds are considered delicacies. The fruit is used for dry decorations. The flower has been a traditional motif in Indian art. The lotus is the national flower of India.

Grasses: Grasses form the second-largest group of flowering plants in the world. They are a very important group of plants as they are used for various purposes, such as making fibre, paper, thatching material for roofs, oil, gum, medicines and many other useful products. The economically important grasses include sugarcane, bamboo and cereals like rice, wheat, millets, maize and so on. Grasses are also important as they provide fodder for domestic animals.

Bamboo: This is a group of large grass-like species that grow in clumps to great heights in many forests of India. They are used for constructing huts and making several useful household articles in rural areas, such as baskets, farm implements, fences, household implements and mats. The young shoots are used as food. It is extensively used in the pulp and paper industry as raw material.

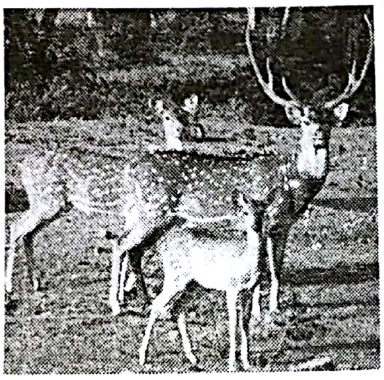
The bamboo plants flower after more than two decades; the plant then dies. The flowering produces thousands of seeds, which results in the slow regrowth of the bamboo. Bamboo is a favourite food of elephants and other large herbivores of the forest, such as *gaur* and deer.

Wild relatives of crop plants: All our present-day cultivated varieties of rice, which are grown for food, come from wild varieties of rice, many of which have originated in India, China and Indonesia. Rice is one of the staple foods of the world. Although the wild varieties are not used as food crops, they are important as they contain genes that can be used to develop disease or pest resistance in crops. Many local varieties of rice have already been lost, as most farmers now grow only high-yielding varieties.

4.8.2 Common Animal Species

Mammals

The common deer species found in India include the *sambar*, *chital*, *barasingha* and barking deer. *Sambar* live in small family parties especially in hilly forested areas and feed mainly on shrubs and leaves of low branches. They are dark brown in colour and have large thick antlers, each having three branches. *Chital* or spotted deer live in large herds in forest clearings where they graze on the grass. They have a rust-brown body with white spots, which camouflages them in the forest. Each antler


AJT JOHNSINGH

Chital

has three branches called tines. The rare *Hangul* deer is found only in Kashmir. It has a magnificent spread of antlers with six branches on each antler. The *Barasingha* or swamp deer has wide hoofs that enable this beautiful animal to live in boggy areas of the *terai*. Each antler has six or more branches. The tiny barking deer lives in many forest areas all over India. It has two ridges on its face and short antlers with only two branches. Its call sounds like the bark of a dog.

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Hangul

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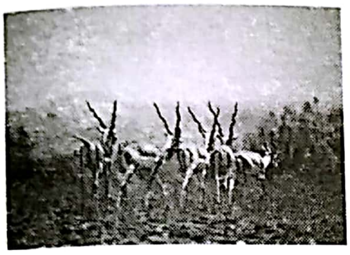
Barasingha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Blackbuck

The blackbuck is the only true antelope found in India. It lives in large herds. The males are black on top and cream below and have beautiful spiral horns that form a 'V' shape. The *chinkara*, also known as the Indian gazelle, is a smaller animal, pale brown in colour, with beautiful curved horns. The rare *Chausingha*, or four-horned antelope, is the only animal in the world that has four horns. The *Nilgai* is the largest of the dryland herbivores. The males are blue-gray in colour. The *Nilgai* have white markings on the legs and head, and short strong spike-like horns.

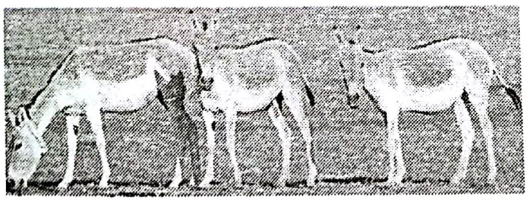
AJT JOHNSINGH

Nilgai

GOBIND SAGAR BHARDWAJ

Chinkara

A very special rare species is the Indian wild ass, endemic to the Little Rann of Kutch. The Himalayan pastures support several species of wild goat and sheep, many of them restricted to the region, like the goral and the Himalayan *Tahr* or mountain goat. A single species, the Nilgiri *Tahr* is found in the Nilgiri and Anamalai hills in South India.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Indian wild ass

The one-horned rhinocerous is now restricted to Assam, but was once found throughout the Gangetic plains. The wild buffalo or *gaur* is now also restricted to the *terai*. The Indian elephant is distributed in the Northeastern and Southern states. It is threatened by habitat loss and poaching for ivory. The *gaur* is found in patches in several well-wooded parts of India.

ERACH BHARUCHA

Nilgiri tahr

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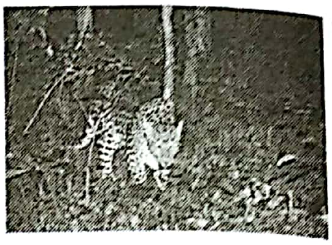
Tiger

The best known predator of our forests is the tiger. Its gold and black stripes hide it perfectly in the forest undergrowth. It preys on herbivores, such as the *sambar* or *chital*, or less frequently on domestic animals. The tiger kills only three or four times a month. Its numbers have declined due to poaching for its skin, and for the supposed magical value of its teeth, claws and whiskers. In the recent past, it has been extensively killed for the supposed medicinal properties of its bones that are used in Chinese medicine.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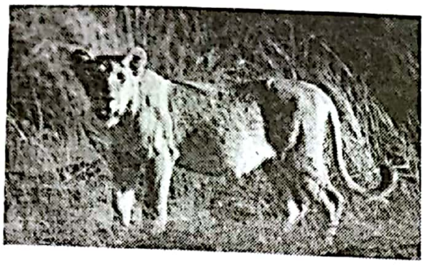
Leopard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Lion

The Asiatic lion is now found only in the Gir forests of Gujarat.

The leopard is more adaptable than the tiger and lives both in thick forests and degraded forest areas. Its beautiful rosette markings camouflage it so perfectly that its prey cannot see its stealthy approach. The smaller jungle cat, which is a light-brown animal and the leopard cat, which is a little bigger than a domestic cat, are very rare. The most typical predator of the Himalayas is the snow leopard, which is very rare and is poached for its beautiful skin, which is pale grey with darker grey ring-like markings.

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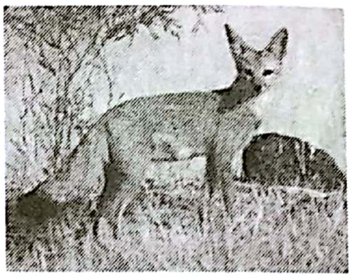
Snow leopard

The wolf, jackal, fox and the wild dog or *Dhole* form a group called canids. Another threatened predator is the Himalayan wolf. The wolves are now highly threatened as they have become increasingly dependent on domestic sheep flocks. Thus, the shepherds constantly devise ways to kill the wolves.

AJT JOHNSINGH

Dhole


ABI TAMIN

Fox

The *Indian pangolin* is found in many parts of India, including national parks such as Corbett and Gir. The Indian pangolin lives mainly in burrows, its habitat include tropical rain forests, lower slopes of mountains, and sub-tropical thorn forests and plains. Like other pangolins, it has a small triangular shaped head and large, overlapping scales to protect its body. Indian pangolins are insectivores that feed on ants and termites.

One of the common monkey species of the forest is the bonnet macaque, which has a red face, a very long tail and a whorl of hair on the scalp which looks like a cap. Our other common monkey is the rhesus macaque, which is smaller and has a shorter tail than the bonnet. A rare macaque is the lion-tailed macaque found only in a few forests of the southern Western ghats and Anamalai ranges. It is black in colour, has long hair, a grey mane and a tassel at the end of its tail that looks like a lion's tail. The common *langur* has a black face and is also known as the Hanuman langur. The rare golden *langur* is golden-yellow in colour and lives along the banks of the Manas River in Assam. The capped *langur* is an uncommon species of Northeast India. The rare black Nilgiri *langur* lives in the southern Western ghats, the Nilgiris and Anamalais.

Lion-tailed macaque

Birds

There are over 1200 bird species found in India in different habitats. Most of our forest birds are specially adapted to life in certain forest types. Some Himalayan species, however, can also be seen in the Western ghats. There are several species of hornbills that live on fruit. They have heavy curved beaks sometimes with a casque on top.

Hornbill

GITA S DATTATRI

Paradise flycatcher

RAMAKRISHNAN SREENIVASAN

Bird of prey

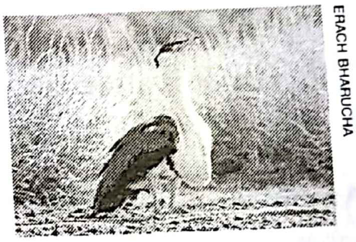
RAMAKRISHNAN SREENIVASAN

Bee-eater

Frugivores such as parakeets, barbets and bulbuls live on fruit and are often seen eating Ficus fruits such as those of banyan and *peepal*.

Insectivorous birds of many species live on forest insects. They include various species of flycatchers, bee-eaters and others. The male paradise flycatcher is a small beautiful white bird with a black head and two long white trailing tail feathers. The female is brown and does not have the long tail feathers. There are several birds of prey such as eagles, falcons and kites, many of which are now endangered.

The grasslands support many species of birds. The most threatened species is the great Indian bustard, a large brown stately bird with long legs, which struts about through grasslands looking for locusts and grasshoppers. Another rare group of threatened birds are the floricans. There are many species of quails, partridges, larks, *munias* and other grain-eating birds that are adapted to the grasslands.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Great Indian bustard

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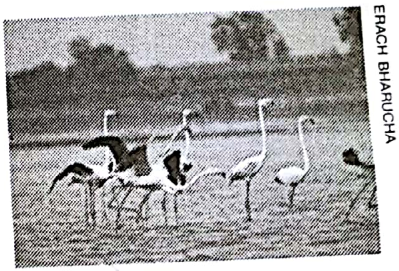
Partridge

There are several species of aquatic birds such as waders, gulls and terns, which live along the seashore and go out fishing many kilometres to the sea. Many of these birds have lost their coastal habitats due to pollution. The freshwater aquatic birds have long legs and are known as waders—such as stilts, egrets and sandpipers. The other group form birds that swim on water like several species of ducks and geese.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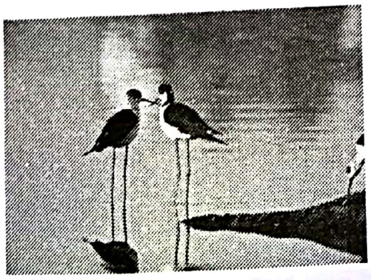
Flamingo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Stilt

There are many species of spectacular large birds associated with water or marshy areas. These include different species of storks, cranes, spoonbills, herons, flamingoes and pelicans. Many aquatic species are migrants. They breed in Northern Europe or Siberia and come to India in thousands during winters.

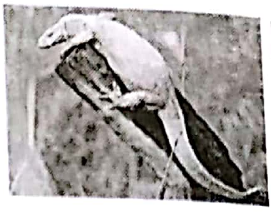
Reptiles

India has a wide variety of lizards, snakes and turtles and tortoises, with a high level of endemism. The lizards include the common garden lizard, the fan-throated lizard, chameleon, skink, common monitor and water monitor. Most of these are threatened due to trade in reptile skins. The Indian snakes include the rock python, the grass snake and the vine snake. We rarely appreciate the fact that only a few species of snakes such as the king cobra, cobra, krait and Russell's viper are poisonous and most other snakes are harmless. The star tortoise and Travancore tortoise are now rare. The Olive Ridley is a marine turtle and comes to nest in large numbers on the coast of Orissa; this unique phenomenon is called the *arribada*. The freshwater turtles include the flap-shell turtle, the Gangeticus, the tented turtles. Many turtles are becoming increasingly rare due to the poaching of adults and eggs. The crocodile is our largest reptile, which is poached for its prized skin. The *gharial* is a species of fish-eating crocodile, endemic to India and is highly threatened.

ERACH BHARUCHA

Fan-throated lizard

King cobra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Monitor lizard

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Star tortoise

RAMAKRISHNAN SREENIVASAN

Gharial

Amphibians

Most of the amphibians found in India are frogs and toads; there is one species of skink. These include several species such as the Indian bullfrog and tree frog. These amphibians are mostly found in the hotspots in the Northeast and the Western ghats. It is now believed that global warming and increasing levels of UV radiation may be seriously affecting amphibian populations in some areas.

Invertebrates

ERACH BHARUCHA

Crab

ERACH BHARUCHA

Beetle

Invertebrates include a variety of taxa that inhabit both terrestrial and aquatic ecosystems. Microscopic animals like protozoa and zooplankton form the basis of the food chain in aquatic habitats. Coral is formed by colonies of polyp-like animals. Worms, mollusks (snails), spiders, crabs, jellyfish and octopus are a few of the better-known invertebrates found in India.

There are more than a million insect species on earth that are known. They include grasshoppers, bugs, beetles, ants, bees, butterflies and moths. India is rich in its butterfly and moth species.

ERACH BHARUCHA

Snail

ERACH BHARUCHA

Spider

Marine life

Marine ecosystems are most frequently associated with fish and crustaceans, like crabs and shrimp, which we use as food. The other endangered species include marine turtles (reptiles) and whales (mammals). There are a large number of species of freshwater fish found in Indian rivers and lakes that are now threatened by the introduction of fish from abroad as well as due to being introduced from one river into another. Fish are also now seriously affected by pollution. Marine fisheries are being over-harvested in our coastal waters and the fish catch has decreased seriously over the last few years. Mechanised boats with giant, small-meshed nets are a major cause of the depletion. There are many endangered fish such as the *Mahseer*, which once grew to over a metre in length. Many species of marine animals, such as whales, sharks and dolphins that live in the Indian Ocean, are now threatened by extinction due to fishing in the deep sea.

For further details see:

- CD ROM on *The Biodiversity of India*, Mapin Publications, Ahmedabad, mapin@icenet.net.
- S H Prater, *The Book of Indian Animals*, BNHS.
- S Ali, *The Book of Indian Birds*, BNHS.

संरक्षण करना/सुरक्षित रखना

4.9 CONSERVATION OF BIODIVERSITY: IN SITU AND EX SITU

4.9.1 In Situ Conservation

The conservation of a species is best done by protecting its habitat along with all the other species that live in it in nature. This is known as *in-situ* conservation, which is conserving a species in its own environment by creating national parks and wildlife sanctuaries. Biodiversity at all levels, as genetic species and as intact ecosystems, can be best preserved *in situ* by setting aside an adequate representation of wilderness as *protected areas*. These should consist of a network of *National Parks and Wildlife Sanctuaries* with each distinctive ecosystem included in the network. Such a network would preserve the total diversity of life of a region.

In the past, national parks and sanctuaries in India were notified to preserve major wildlife species such as tigers, lions, elephants and deer. The objective of these areas should be expanded to the preservation of relatively intact natural ecosystems, where biological diversity, from microscopic unicellular plants and animals to the giant trees and large mammals, can all be preserved.

However, species cannot be protected individually as they are all interdependent—the whole ecosystem must be protected. The biologist's viewpoint deals with areas that are relatively species-rich, or those where rare, threatened or endangered species are found, or those with endemic species. As rare endemic species are found only in a small area, these easily become extinct due to human activity. Such areas must be given an added importance as their biodiversity is a special feature of the region.

Animals such as elephants require different types of habitat to feed in during different seasons. They utilise open grasslands after the rains when the young grass shoots are highly nutritious. As the grasses dry, the elephants move into the forest to feed on foliage from the trees. A PA

Table 4.4 Representative national parks and wildlife sanctuaries in India

No	Name	State	Established	Area (in km^2)
1	Campbell Bay National Park	Andaman and Nicobar	1992	426.23
2	Sri Venkateswara National Park	Andhra Pradesh	1989	353
3	Namdapha National Park	Arunachal Pradesh	1974	1985.24
4	Kaziranga National Park	Assam	1974	471.71
5	Manas National Park	Assam	1990	500
6	Valmiki National Park	Bihar		461.6
7	Indravati National Park	Chhattisgarh	1981	1258.37
8	Kanger Ghati National Park (Kanger Valley)	Chhattisgarh	1982	200
9	Gir National Park	Gujarat	1965	258.71
10	Gulf of Kachchh Marine National Park	Gujarat	1980	162.89
11	Dachigam National Park	Jammu and Kashmir	1981	141
12	Hemis National Park	Jammu and Kashmir	1981	4100
13	Salim Ali National Park	Jammu and Kashmir		9.07
14	Bandipur National Park	Karnataka	1974	874.20
15	Kudremukh National Park	Karnataka	1987	600.32
16	Nagarhole National Park (Rajiv Gandhi National Park)	Karnataka	1988	643.39
17	Eravikulam National Park	Kerala	1978	97
18	Periyar National Park	Kerala	1982	305
19	Silent Valley National Park	Kerala	1980	237
20	Bandhavgarh National Park	Madhya Pradesh	1982	448.85
21	Kanha National Park	Madhya Pradesh	1955	940
22	Panna National Park	Madhya Pradesh	1981	542.67
23	Borivili National Park (Sanjay Gandhi National Park)	Maharashtra	1969	104
24	Pench National Park	Maharashtra	1977	758
25	Tadoba National Park	Maharashtra	1955	625
26	Balphakram National Park	Meghalaya	1986	220
27	Desert National Park	Rajasthan	1980	3162
28	Mount Abu Wildlife Sanctuary	Rajasthan	1960	288.84
29	Ranthambore National Park	Rajasthan	1981	392
30	Sariska National Park	Rajasthan	1955	866
31	Khangchendzonga National Park	Sikkim	1977	1784
32	Mudumalai National Park	Tamil Nadu	1940	321.55
33	Dudhwa National Park	Uttar Pradesh	1977	490.29
34	Valley of Flowers National Park	Uttarakhand	1982	87.50
35	Corbett National Park	Uttaranchal	1921	1318.5
36	Sundarbans National Park	West Bengal	1984	1330.12

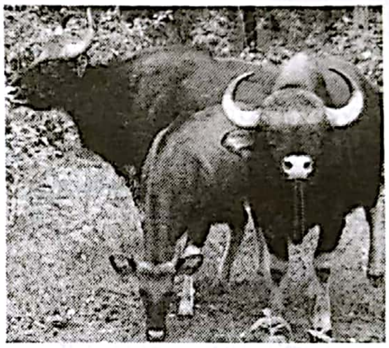
that is meant to protect elephants must, therefore, be large enough and include diverse habitat types to support a complete complement of interlinked species.

Wildlife sanctuaries and national parks of India: There are 589 protected areas in India, of which 89 are national parks and 500 are wildlife sanctuaries. They include a variety of ecosystems and habitats. Some have been created in order to protect highly endangered species of wild plants and animals found nowhere else in the world.

The Great Himalayan National Park is the largest sanctuary in this ecosystem and is one of the last homes of the beautiful snow leopard. The Dachigam sanctuary is the only place where the rare *Hangul* or Kashmir stag is found. There are several sanctuaries in the *terai* region— the Kaziranga National Park is the most famous and is home to the rhinocerous apart from elephant, *gaur*, wild boar, swamp deer and hog deer in large numbers, as well as tigers and leopards. Its bird life is extremely rich and includes ducks, geese, pelicans and storks. The Manas sanctuary, in addition to the above *terai* species, also includes the rare golden *langur* and the very rare pygmy hog, the smallest wild boar in the world. The florican is found only in a few undisturbed grasslands in the *terai* sanctuaries.

AJIT JOHNSINGH

Rhino


AJIT JOHNSINGH

Gaur

KALYAN VARMA

Golden langur

In the sal forests of Madhya Pradesh, there are several PAs. Kanha offers a wonderful opportunity to observe wild tigers on elephant back. It is the only PA in which a sub-species of the *barasingha* is found.

Bharatpur is one of the most famous water-bird sanctuaries in the world. Thousands of ducks, geese, herons and other wading birds can be seen here. This is the only home of the very rare Siberian crane, which migrates to India every winter. During the last 20 years, the 30 or 40 Siberian cranes have dwindled to only 2 or 3. During 2002–03, no cranes were seen and it is possible that this beautiful bird will never again come to India.

In the Thar desert, wildlife is protected in the Desert National Park. Here, large numbers of blackbuck, *nilgai* and *chinkara* can be seen. The great Indian bustard lives in these arid lands.

Ranthambore was the most well-known sanctuary for observing tigers in the wild till about 3 or 4 years ago. Since then, many tigers have been killed by poachers.

The Great and the Little Rann of Kutch have been made into sanctuaries to protect the very rare wild ass, the flamingo, the star tortoise and the desert fox. In Gujarat, the Gir sanctuary protects the last population of the majestic Asiatic lion. This thorn and deciduous forest is also the home of large herds of *chital*, *sambar* and *nilgai*.

The sanctuaries of the Western ghats and associated hill ranges protect some of the most diverse forest types in the country. The few examples of highly-threatened species include the

Malabar giant squirrel, the flying squirrel and a variety of hill birds, several species of amphibians, reptiles and insects. These regions are also rich in highly endemic plant life. Sanctuaries such as Bhimashankar, Koyana, Chandoli and Radhanagari preserve this rich flora in Maharashtra; Bandipur, Bhadra, Dandeli and Nagarhole in Karnataka; Eravikulam, Parambikulam, Periyar and the Silent Valley in Kerala.

In the Nilgiri hills, the rich forest sanctuaries protect some of the last pockets of the Indian elephant in South India. Examples include Bandipur, Mudumalai, Wyanad and Bhadra. During the last 10 years, a large number of the great tusker elephants of this region have been ruthlessly killed for their ivory. Now, very few of these magnificent animals are left in these jungles.

Two important sanctuaries meant for preservation of coastal ecosystems are the Chilika lake in Orissa and Point Calimere in Tamil Nadu. The Sunderbans protect the largest mangrove delta in India. The Marine National Park in Gujarat protects shallow areas in the sea, islands, coral reefs and extensive mudflats.

Over a hundred PAs have been created in the Andaman and Nicobar islands to preserve their very special island ecosystems.

CASE STUDY 3

Orissa: Olive Ridley turtles

Every year at Gahirmatha, Rushikulya and the mouth of the Devi river on the Orissa coast, hundreds of thousands of Olive Ridley turtles congregate on the beach, between December and April, for mass nesting—the *arribada*. This was the largest nesting site for Olive Ridleys in the world. In 1999, by the end of March it was estimated that around 200,000 turtles had nested at the Gahirmatha beach. Marine biologists believe that only one out of every 1000 eggs actually matures into an adult.

There are severe threats to these nesting sites. Shrinking nesting sites, construction of roads and buildings close to these rookeries, and other infrastructure development projects hamper nesting. Trawler fishing is another large threat to the turtles. After its 'discovery' in 1974, the beach was notified as a sanctuary (the Bhitarkanika sanctuary) and was closed for hunting. Recognising the threat to turtles from fishing by large trawlers, the Orissa Marine Fisheries Regulation Act was passed in 1982. This Act prohibits trawling within 10 km of the coastline throughout the state and makes it mandatory for all trawlers to use Turtle Excluder Devices (TEDs). In 2001, the State Government of Orissa declared that a five-month period between January and May should constitute a no-fishing season for a distance of 20 km from the coastline.

Apart from these initiatives, 'Operation Kachhapa' is being coordinated by the Wildlife protection Society of India, Delhi and Wildlife Society of Orissa with many local NGOs as partners. The Orissa Forest Department, WII, Dehra Dun and the Coast Guard are also involved in the project.

The need for an integrated protected area system (IPAS): Protected areas, to be effective, must be established in every biogeographic region. A relatively larger representation must be included of highly fragile ecosystems, areas of high species diversity or high endemism. PAs must also be integrated with each other, by establishing corridors between adjacent areas wherever possible so that wildlife can move between them.

In our country, which has a rapidly growing human population, it is not easily feasible to set aside more and more land to create PAs. The need to provide a greater amount of land for agricultural and other needs has become an increasing cause of concern in land and resource management. This forms a major impediment for creating new PAs. Having said this, there is an urgent need to add to our PAs to preserve our very rich biological diversity. Much of the natural wilderness has already undergone extensive changes. The residual areas that have high levels of species richness, endemism or endangered plants and animals must be notified as national parks and wildlife sanctuaries. Other areas can be made into Community Conserved Areas which are managed by local people.

The International Union for Conservation of Nature and Natural Resources (IUCN) states that it is essential to include at least 10% of all ecosystems as protected areas if biodiversity is to be conserved in the long term.

India has only 5% of land in its 589 protected areas in 2004. However, much of this includes plantations of sal or teak, which were developed for timber in the past and are thus relatively poor in diversity and have a low level of 'naturalness'. There are only a few good grasslands left in our country that are notified as PAs. Some are merely over-grazed wastelands in areas that were once flourishing grasslands. Most of these areas have a low biological value and need careful management to allow them to revert to a more natural state, with their full complement of plants and animals. Only a few wetlands have been made into sanctuaries. These require better management.

A major strategy to reduce impacts on the biodiversity of the PAs should be to provide a sustainable source of resources for local people living around them. A PA curtails their traditional grazing practices and access to fuelwood sources. These resources must be provided by developing them in the buffer areas. Plantations of fuelwood and good grassland management in areas outside PAs can help reduce the pressure on the habitat of wildlife within the PA. Good management practices must ensure that local people derive a direct economic benefit from the presence of the PA. Involving local people in Protected Area Management and developing tourist facilities that support the income generation for local people helps in enlisting their support for the PA.

A carefully-designed management plan which incorporates an 'ecodevelopment' component aimed at providing a source of fuelwood, fodder and alternate income generation for local people, is an important aspect of PA management.

There are several species of plants and animals that survive without protection outside our current network of PAs. As it is not practical to notify more PAs without affecting the lives of people, alternate strategies such as Community Reserves or Community Conserved Areas (CCAs) need to be created. These should be managed by local people to bring about the conservation of biodiversity, while using the area's resources in an equitable and sustainable way. A CCA must have specific conservation goals that can be achieved without compromising the area's utilitarian potential.

A major drive for conservation of biological diversity can only come from a mass environmental education program on the value of protecting our dwindling biological resources.

4.9.2 Ex Situ Conservation

There are situations in which an endangered species is so close to extinction that unless alternate methods are instituted, the species may be rapidly driven to extinction. This strategy is known as ex situ conservation, that is, conserving the species outside its natural habitat in a carefully controlled situation such as a botanical garden for plants, a zoological park for animals or within the care of humans where there is expertise to multiply the species under artificially managed conditions. Finally, a successful breeding programme ensures that a species is reintroduced into its original wild habitat. This requires rehabilitation of the degraded habitat and removal of the other causes such as poaching, disturbances, or other artificial influences that have been the primary cause of reducing the population of the species. These breeding programs for rare plants and animals are, however, more expensive than managing a PA.

Another form of preserving a plant is by preserving its germplasm in a gene bank so that it can be used if needed in future. However, this is rather expensive.

When an animal is on the brink of extinction, it must be carefully bred so that in-breeding does not lead to the genetic composition becoming weak. Breeding from the same stock can lead to poorly-adapted progeny or even an inability to get enough offspring.

Modern breeding programmes are undertaken in zoos that provide for all the animal's needs, including enclosures that simulate their wild habitats. There may also be a need to assist breeding artificially. Thus, while most zoos are meant to provide visitors with a visual experience of seeing a wild animal at close quarters and provide the visitors with information about the species, a modern zoo has to go beyond these functions to include breeding of endangered species as a conservation measure.

In India, successful ex situ conservation programmes have been carried out for all our three species of crocodiles; this has been highly successful. The most successful example is the Madras Crocodile Trust Bank, which has grown from 10 to 8,035 crocodiles and the crocodiles here lay two clutches of eggs a year, compared to one in the wild! Another recent success has been the breeding of the very rare pygmy hog in the Guwahati zoo. The Delhi zoo has successfully bred the rare Manipur brow-antlered deer.

CASE STUDY 4

Conservation programmes

Crocodile conservation: Crocodiles have been threatened as their skin is used for making leather articles. This led to the near extinction of crocodiles in the wild in the 1960s in India.

A crocodile breeding and conservation programme was initiated in 1975 to protect the remaining population of crocodilians in their natural habitat and by creating breeding centres. It is perhaps one of the most successful ex situ conservation breeding projects in the country.

Crocodiles have been extensively bred in over 30 captive breeding centres, zoos and other sites where successful breeding takes place. Thousands of crocodiles of all three species have been bred and restocked in 20 natural water bodies.

Project Elephant: Project Elephant was launched in 1992 to ensure the long-term survival of a viable population of elephants in their natural habitats in North and North-eastern India and South India. In situ conservation is being implemented in 12 states. Despite this, our elephant herds are under threat as their habitat is shrinking and their migration routes are disrupted by human activities.

(Continued)

(Continued)

Vulture breeding program: The last two decades have seen a drastic decline in the number of vultures across India. Three of the nine species in India are *critically endangered* according to the IUCN. Visceral gout, a disease in birds, caused by diclofenac, an anti-inflammatory drug, is known to be the main cause of the crash in populations. Diclofenac is given to sick (and/or working) cattle to reduce their pain so that they can work on farmlands for longer periods of time. Once the cattle die, they are left out in the open for vultures—nature's most efficient scavengers that play a major role in keeping the environment clean. However, vultures feeding on the flesh of cattle are poisoned by diclofenac, which causes renal failure, visceral gout and eventually death. Meloxicam has now been recommended as an alternative to diclofenac. Furthermore, the Government of India has also banned diclofenac.

In 2001, a Vulture Conservation Breeding Centre was established in Pinjore in Haryana by the Bombay Natural History Society (BNHS) and the Haryana Forest Department. The centre houses white-backed vultures (15 adults and 9 juveniles), long-billed vultures (3 adults and 25 juveniles), slender-billed vultures and the Himalayan griffon. One hundred pairs of vultures are projected to be released by 2020.

Conservation of cultivars and livestock breeds: There were an estimated 30,000 varieties of rice grown in India till about 50 years ago. Now, only few of these are still grown. The new varieties which are now being cultivated everywhere have been developed using the germplasm of these original types of rice. If all the traditional varieties vanish completely, it will be difficult to develop new disease-resistant varieties of rice in the future. Several varieties have been preserved in gene banks. However, this is both very expensive and risky. Encouraging farmers to continue to grow several traditional varieties is, thus, an important concern for the future of mankind. At present, gene bank collections have over 34,000 cereals and 22,000 pulses.

In the past, domestic animals were selected and bred for their ability to adapt to local conditions. Traditional agro-pastoralists in India have selectively bred livestock for 2,000–3,000 years. India has 27 breeds of cattle, 40 breeds of sheep, 22 breeds of goat and 8 breeds of buffaloes. These traditional breeds must be maintained for their genetic variability.

CASE STUDY 5

Wonder sheep

Generally speaking, Indian sheep production is constrained due to challenges of low prolificacy (fertility) and parasitic worms. In order to make the sheep industry more profitable in Maharashtra, Bon Nimbkar, the founder of the Nimbkar Agricultural Research Insititute (NARI) in Phaltan, in Maharashtra was looking to develop prolific, worm-resistant meat sheep that could adapt to the local conditions of the state. It was known that the Booroola merino sheep in Australia has a high prolificacy with multiple births. A strategy to import the high prolificacy gene from Australia was researched. It was then realised that the large-bodied Australian sheep in actual fact came from the Sunderbans in West Bengal!

So the small course-woolled sheep which has high prolificacy and is worm-resistant in the wet conditions in West Bengal actually held the secret of the growth of the wool industry in early colonial Australia. The Garole 'wonder sheep' can now enable a more productive sheep industry in Maharashtra. This case study is indicative of the importance of maintaining genetic variability of breeds.

CASE STUDY 6

Beej bachao andolan (Save the seeds movement)

This movement began in the Himalayan foothills. The members collected seeds of diverse crops in Garhwal. The movement has successfully conserved hundreds of local rice varieties, *rajma* (kidney beans), pulses, millets, vegetables, spices and herbs. Many different varieties are being grown as an outcome of this programme in local farmers' fields. This has also been supported by local women's groups who felt these varieties were better than those provided by the green revolution. In contrast, men who were interested in cash returns in a short time found it difficult to appreciate the benefits of growing indigenous varieties.

Summary

- Biological diversity refers to the variation of life forms at three levels—genetic variability within a species, the variety of species within a community and the organisation of species in an ecosystem.
- Biological diversity provides a variety of environmental goods and services. These can be categorised as consumptive and productive use values, socio-cultural values, aesthetic values and option values.
- India is a bio-rich nation, it ranks among the top 15 counties that are exceptionally rich in species diversity, many of which are endemic to the country and found nowhere else in the world.
- Areas that are rich in species diversity are called 'hotspots' of diversity. India's 'hotspots' are concentrated in three areas—the Andaman and Nicobar islands, forests of the Northeastern states and forests of the Western ghats.
- Threats to biodiversity include: habitat loss due to rapid urbanisation and industrialisation, poaching for wildlife for short-term economic gain, and finally conflicts arising from human–wildlife coexistence.
- In situ conservation refers to protecting species in their natural habitat by setting aside an adequate representation of wilderness as Protected Areas (PAs), consisting of a network of national parks and wildlife sanctuaries.
- These PAs must be integrated with each other, by establishing corridors between adjacent areas wherever possible so that wildlife can move between them.
- Ex situ conservation refers to protecting species away from their natural habitat, in conditions which can be closely controlled and monitored.

Questions

1. Define biological diversity.
2. What are some of the major causes of species loss in the 21st century? Provide at least three causes.

3. Discuss any two common plant species, in terms of their description and use.
4. What are some of the strategies that can be applied to protect biodiversity of India's protected areas?
5. What is in situ and ex situ conservation? Provide examples of each.
6. List three indirect values of biodiversity.
7. Give at least three examples of each of the following.
   (a) Endangered plants
   (b) Endangered animals
   (c) Endangered birds

Endangered Plant → Shrubs & Climber

Animals - tiger, Elephant, rhinoceroses

Birds → Siberian Crane

The Inidan Bust

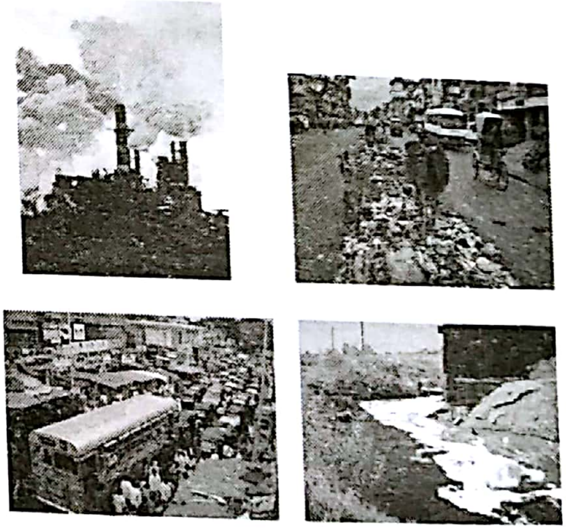
Unit 5

Pollution

Let's understand

- The definition of pollution
- The causes, effects and control measures of pollution
- The various types of pollution
- About solid waste management
- The causes, effects and control measures for urban and industrial waste
- What the role of an individual in prevention of pollution is
- How to manage disasters such as floods, earthquakes, cyclones and landslides

> 'We spray our elms, and the following spring, the trees are silent of robin song, not because we sprayed the robins directly but because the poison traveled step by step through the now familiar elm-earthworm-robin cycle.'
>
> —*Rachael Carson*



This quotation appeared in Rachael Carson's book entitled *Silent Spring*. In the years following the publication of *Silent Spring* in 1962, the book inspired controversy and initiated a major change in the thinking about the safety of using pesticides and other toxic chemicals.

5.1 DEFINITION

Pollution is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings. This occurs when only short-term economic gains are considered at the cost of long-term ecological benefits for humanity. No phenomenon has led to greater ecological changes than that created by humans. In the last few decades, we have contaminated the air, water and land on which life itself depends with a variety of waste products.

Pollutants include solid, liquid and gaseous substances present in greater than natural abundance, produced by human activity, which have a detrimental effect on the environment. The nature and concentration of a pollutant determines the severity of its detrimental effects on human health. An average human requires about 12 kg of air each day, which is nearly 12–15 times greater than the amount of food we eat. So, even a small concentration of pollutants in the air becomes more significant in comparison to similar levels present in food. Pollutants that enter the water have the ability to spread to distant places, especially in the marine ecosystem.

From an ecological perspective, pollutants can be classified as follows:

Degradable or non-persistent pollutants: These can be rapidly broken down by natural processes; for example, domestic sewage and discarded vegetables.

Slowly degradable or persistent pollutants: These are pollutants that remain in the environment for many years in an unchanged condition and take decades or longer to degrade; for example, DDT (pesticides) and most plastics.

Non-degradable pollutants: These cannot be degraded by natural processes. Once they are released into the environment, they are difficult to eradicate and continue to accumulate; for example, toxic elements like lead or mercury and nuclear waste.

The causes, effects and control measures with respect to different kinds of pollution are described in detail.

5.2 AIR POLLUTION

5.2.1 The History of Air Pollution

The origin of air pollution on earth can be traced back to the time when humans started using firewood as a means of cooking and heating. Hippocrates mentioned air pollution in 400 BCE. With the discovery and increased use of coal, air pollution became more pronounced, especially in urban areas. It was recognised as a problem 700 years ago in London in the form of smoke pollution, which prompted King Edward I to make the first anti-pollution law to restrict people from using coal for domestic heating in the year 1273. In the year 1300, another Act banning the use of coal was passed; defying the law led to imposition of capital punishment. In spite of this, air pollution became a serious problem in London during the Industrial Revolution due to the widespread use of coal in industries. The earliest recorded major disaster was the 'London smog' that occurred in 1952, which resulted in more than 4000 deaths due to the accumulation of air pollutants over the city for five days.

In Europe, around the middle of the 19th century, a black form of the peppered moth began appearing in industrial areas. In its regular form, the peppered moth is well camouflaged when on a clean, lichen-covered tree. However, this peppered pattern was easily spotted and picked up by birds on the smoke-blackened bark of trees in industrial areas. So, while the normal pepper-patterned moths were successful in surviving in clean non-industrial areas, only black-coloured moths were successfully camouflaged in industrial areas. Thus, with the spread of industrialisation, an increased incidence of black forms has been observed, not only in the peppered moth but also in many other moths. This is a classic case of pollution leading to adaptation.

Air pollution began to increase in the beginning of the 20th century with the development of transportation systems and the large scale use of petrol and diesel. Pollution due to auto exhaust remains a serious environmental issue in many developed and developing countries, including India.

CASE STUDY 1

Bhopal gas tragedy

The greatest industrial disaster leading to serious air pollution took place in Bhopal, where the extremely poisonous methyl isocyanide gas was accidentally released from Union Carbide's pesticide manufacturing plant, on the night of 2 December 1984. The effect of this disaster on human health has been in the hundreds of thousands, with the ensuing soil and groundwater contamination felt even today. Over twenty-five years later, the verdict of this tragedy still continues to raise controversy and expose the lack of 'green laws' in India when it comes to industrial disasters. The accused from the Bhopal disaster were sentenced to two years of imprisonment – the maximum charge for causing death by negligence – along with a fine. An appeal to review this punishment and modify laws is now underway.

What in your opinion would be a more appropriate verdict to this tragedy?

cogNote B

5.2.2 Structure of the Atmosphere

To understand how pollutants travel and cause an impact on us, it is important to understand the structure of the atmosphere. The atmosphere is normally composed of 79% nitrogen, 20% oxygen and 1% as a mixture of carbon dioxide, water vapour and trace amounts of several other gases such as neon, helium, methane, krypton, hydrogen and xenon. The general structure of the atmosphere has several important features of relevance to environmental problems. The atmosphere is divided into several layers (Fig. 5.1).

The innermost layer, the *troposphere*, extends 17 km above sea level at the equator and about 8 km over the poles. It contains about 75% of the mass of the earth's air. The fragility of this layer is obvious from the comparsion that if the earth were an apple, this particular layer would be no thicker than the apple's skin. Temperature declines with altitude in the troposphere. At the top of the troposphere, temperatures abruptly begin to rise. This boundary where temperature reversal occurs is called the *tropopause*.

The tropopause marks the end of the troposphere and the beginning of the *stratosphere*, the second layer of the atmosphere. The stratosphere extends from 17–48 km above the earth's surface. While the composition of the stratosphere is similar to that of the troposphere, it has two major differences. The volume of water vapour here is about 1000 times less, while the volume of ozone is about 1000 times greater. The presence of ozone in the stratosphere prevents about 99% of the sun's harmful ultraviolet (UV) radiation from reaching the earth's surface, thereby protecting humans from cancer and from damage to the immune system. This layer does not have clouds; hence, aeroplanes fly in this layer as it creates less turbulence. Temperature rises with

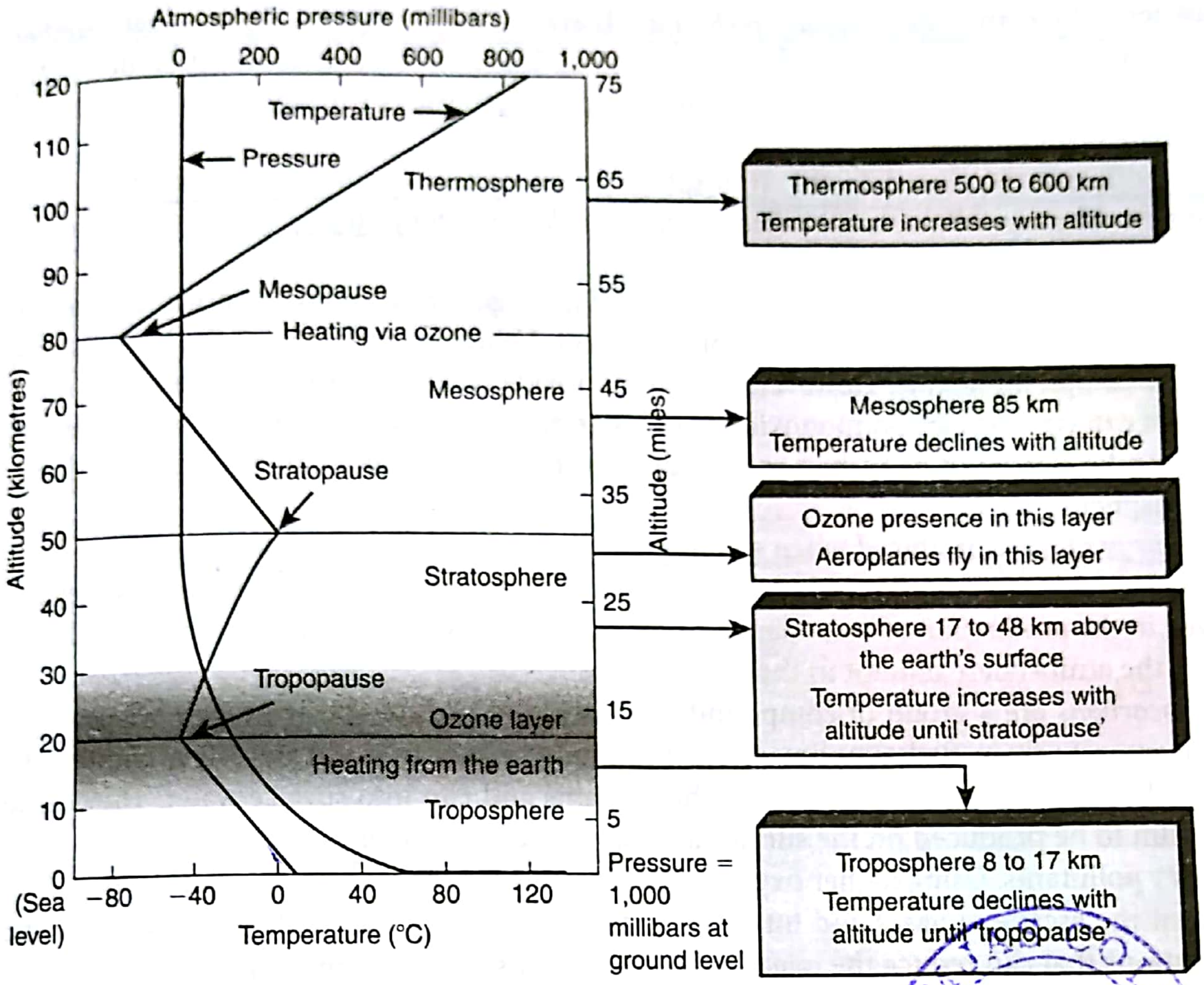

Atmospheric pressure (millibars)
0
200
400
600
800
1,000
120
110
100
90
80
70
60
50
40
30
20
10
0
(Sea level)
Altitude (kilometres)
Temperature
Pressure
Thermosphere
Mesopause
Heating via ozone
Mesosphere
Stratopause
Stratosphere
Tropopause
Ozone layer
Heating from the earth
Troposphere
−80
−40
0
40
80
120
Temperature (°C)
75
65
55
45
35
25
15
5
Altitude (miles)
Pressure = 1,000 millibars at ground level
Thermosphere 500 to 600 km
Temperature increases with altitude
Mesosphere 85 km
Temperature declines with altitude
Ozone presence in this layer
Aeroplanes fly in this layer
Stratosphere 17 to 48 km above the earth's surface
Temperature increases with altitude until 'stratopause'
Troposphere 8 to 17 km
Temperature declines with altitude until 'tropopause'

Fig. 5.1 Structure of the atmosphere

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altitude in the stratosphere, until there is another reversal. This point is called the *stratopause* and it marks the end of the stratosphere.

In the next layer, the *mesosphere*, temperature decreases with altitude, falling up to −110°C at the top. Above this is a layer where ionisation of the gases is a major phenomenon, thus raising the temperature. This layer is called the *thermosphere*. Only the lower troposphere is routinely involved in our weather and, hence, air pollution. The other layers are not significant in determining the level of air pollution.

5.2.3 Types and Sources of Air pollution

What is Air Pollution?

Air pollution occurs due to the presence of undesirable solid or gaseous particles in the air, in quantities that are harmful to human health and the environment. The air may become polluted by natural causes such as volcanoes, which release ash, dust, sulphur and other gases, or by forest fires that are occasionally caused by lightning. However, unlike pollutants created by human activity, naturally occurring pollutants tend to remain in the atmosphere for a short time and do not lead to permanent atmospheric change.

Pollutants that are emitted directly from identifiable sources are produced both by natural events (dust storms and volcanic eruptions) and by human activities (emission from vehicles, industries). These are called *primary pollutants.* There are five primary pollutants that together contribute to about 90% of the global air pollution. These are carbon oxides (CO and CO_2), nitrogen oxides, sulphur oxides, volatile organic compounds (mostly hydrocarbons) and suspended particulate matter.

The pollutants produced in the atmosphere when certain chemical reactions take place among the primary pollutants are called *secondary pollutants*; for example, sulphuric acid, nitric acid and carbonic acid.

Carbon monoxide is a colourless, odourless and toxic gas produced when organic materials like natural gas, coal or wood are incompletely burnt. Vehicular exhausts are the largest single source of carbon monoxide. However, carbon monoxide is not a persistent pollutant. Natural processes can convert carbon monoxide to other compounds that are not harmful. Therefore, the air can be cleared of its carbon monoxide if no new carbon monoxide is introduced into the atmosphere.

Sulphur oxides are produced when sulphur containing fossil fuels are burnt.

Nitrogen oxides are found in vehicular exhausts. Nitrogen oxides are significant, as they are involved in the production of secondary air pollutants such as ozone, which is harmful at lower levels of the atmosphere but not in the stratosphere.

Hydrocarbons are a group of compounds consisting of carbon and hydrogen atoms. They either evaporate from fuel supplies or are remnants of fuel that did not burn completely. Hydrocarbons are washed out of the air when it rains and run into surface water. They cause an oily film to be produced on the surface and do not cause problems until they react to form secondary pollutants. Using higher oxygen concentrations in the fuel–air mixture, using valves to prevent the escape of gases and fitting catalytic converters in automobiles are some of the modifications that can reduce the release of hydrocarbons into the atmosphere.

Particulates are small pieces of solid material (for example, smoke particles from fires, bits of asbestos, dust particles and ash from industries) dispersed into the atmosphere. The effects of particulates range from soot to the carcinogenic (cancer causing) effects of asbestos, dust particles and ash from industrial plants that are dispersed into the atmosphere. Repeated exposure

Table 5.1 Types of particulates

Term	Meaning	Examples
Aerosol	General term for particles suspended in air	Sprays from pressurised cans
Mist	Aerosol consisting of liquid droplets	Sulphuric acid mist
Dust	Aerosol consisting of solid particles that are blown into the air or are produced from larger particles by grinding them down	Dust storm
Smoke	Aerosol consisting of solid particles or a mixture of solid and liquid particles produced by chemical reactions such as fires	Cigarette smoke, smoke from burning garbage
Fume	Generally means the same as smoke but often applies specifically to aerosols produced by condensation of hot vapours of metals	Zinc/lead fumes
Plume	Geometrical shape or form of the smoke coming out of a chimney	
Fog	Aerosol consisting of water droplets	
Smog	Term used to describe a mixture of smoke and fog	

to particulates can cause them to accumulate in the lungs and interfere with their ability to exchange gases.

Lead is a major air pollutant that remains largely unmonitored and is emitted by vehicles. High lead levels have been reported in the ambient air in metropolitan cities. Leaded petrol is the primary source of air borne lead emissions in Indian cities. The use of unleaded petrol is one way of reducing this pollutant.

Pollutants are also found indoors from the infiltration of polluted air from outside and from various chemicals used or produced inside buildings. Both indoor and outdoor air pollution are equally harmful.

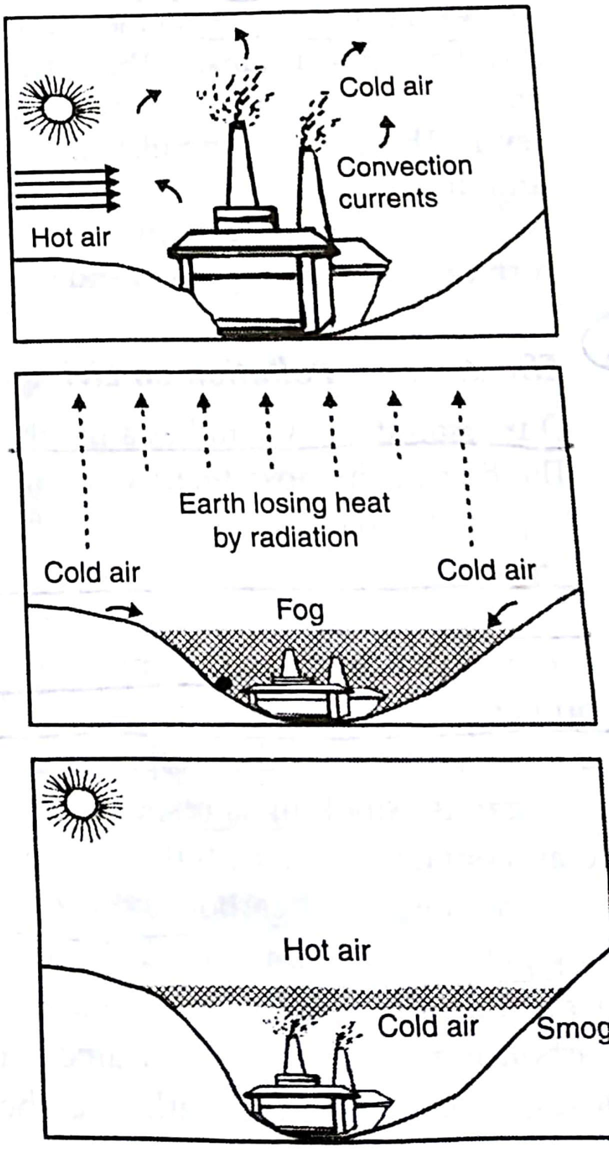
What Happens to Pollutants in the Atmosphere?

Once pollutants enter the troposphere they are transported downwind, diluted by the large volume of air, and transformed through physical or chemical changes. Alternatively, pollutants may be removed from the atmosphere by rain during which they become attached to water vapour to subsequently form rain or snow that falls to the earth's surface. The atmosphere normally disperses pollutants by mixing them in the very large volume of air that covers the earth. This dilutes the pollutants to acceptable levels. The rate of dispersion, however, varies in relation to the following aspects.

Topography

Normally, as the earth's surface becomes warmed by sunlight, the layer of air in contact with the ground is also heated by convection. This warmer air is less dense than the cold air above it, so it rises. In this manner, the pollutants produced in the surface layer are effectively dispersed.

However, on a still evening, the process is reversed. An hour or two before sunset after a sunny day, the ground starts to lose heat and the air near the ground begins to cool rapidly. Due to the absence of wind, a static layer of cold air is produced as the ground cools. This, in turn, induces the condensation of fog. The morning sun cannot initially penetrate this fog layer. The cold air being dense cannot rise and is trapped by the warm air above; it cannot move out of the area due to the surrounding hills. The topographic features resemble a closed chemical reactor in which the pollutants are trapped. This condition often continues through the cool night and reaches its maximum intensity before sunrise. When the morning sun warms the ground, the air near the ground also warms up and rises within an hour or two. This may be broken up by strong winds. In cold regions, this situation can persist for several days. Such a situation is known as smog (smoke + fog).

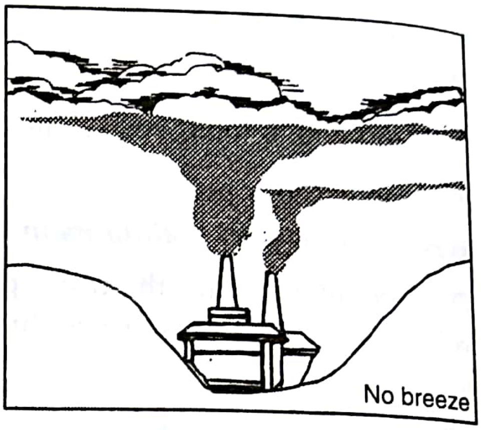


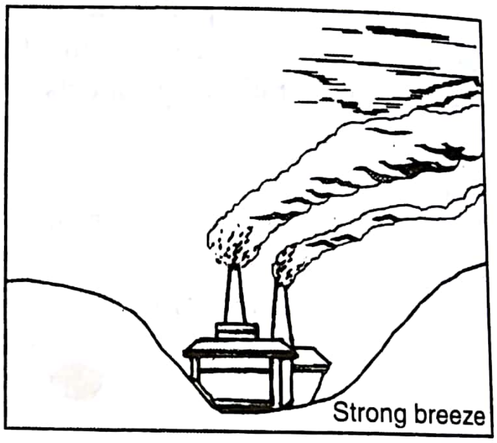
Meteorological conditions

The velocity of the wind affects the dispersal of pollutants. Strong winds mix the polluted air more rapidly with the surrounding air, diluting the pollutants rapidly. When the wind velocity is low, mixing takes place but at a slower rate and the concentration of pollutants remains high.

When sulphur dioxide and nitrogen oxides are transported by prevailing winds they form secondary pollutants such as nitric acid vapour, droplets of sulphuric acid and particles of sulphate and nitrate salts. These chemicals descend on the earth's surface in two forms—wet (as acidic rain, snow, fog and cloud vapour) and dry (as acidic particles). The resulting mixture is called acid deposition or *acid rain.*

Acid deposition has many harmful effects, especially when the pH falls below 5.1 for terrestrial systems and below 5.5 for aquatic systems. It contributes to human respiratory diseases such as like bronchitis and asthma which can cause premature death. It also damages statues, buildings, metals and car finishes. Acid deposition can damage tree foliage directly, but the most serious effect is the weakening of trees so they become more susceptible to other types of damage. The nitric acid and nitrate salts in acid deposition can lead to excessive soil nitrogen levels. This can over-stimulate the growth of other plants and intensify the depletion of other important soil nutrients, such as calcium and magnesium, which in turn can reduce tree growth and vigour.


No breeze


Strong breeze

Ans ①

Effects of Air Pollution on Living Organisms

Our respiratory system has a number of mechanisms that help protect us from air pollution. The hair in the nose filters out large particles. The sticky mucus in the lining of the upper respiratory tract captures smaller particles and dissolves some gaseous pollutants. When the upper respiratory system is irritated by pollutants, sneezing and coughing expel the contaminated air and mucus. Prolonged smoking or exposure to air pollutants can overload or break down these natural defenses, causing or contributing to diseases such as lung cancer, asthma, chronic bronchitis and emphysema. Elderly people, infants, pregnant women and people with heart disease, asthma or other respiratory diseases are especially vulnerable to air pollution.

Cigarette smoking is responsible for the greatest exposure to carbon monoxide. Exposure to air containing even 0.001% of carbon monoxide for several hours can cause collapse, coma and even death. As carbon monoxide remains attached to the hemoglobin in the blood for a long period, it accumulates and reduces the oxygen carrying capacity of blood. This impairs perception and thinking, slows reflexes and causes headache, drowsiness, dizziness and nausea. Carbon monoxide in heavy traffic causes headache, drowsiness and blurred vision; in large doses, it can even cause death by carbon monoxide poisoning.

Sulphur dioxide, nitrogen oxides, especially NO, and suspended particles in the air aggravate our respiratory tract, leading to bronchitis and asthma. Prolonged exposure to these particles damages lung tissue and contributes to the development of chronic respiratory disease and cancer.

Many volatile organic compounds (such as benzene and formaldehyde) and toxic particulates (such as lead and cadmium) can cause mutations, reproductive problems or cancer. The repeated inhalation of ozone, a component of photochemical smog, causes coughing, chest pain, breathlessness and irritation of the eye, nose and the throat (Fig. 5.2).

Effects on Plants

The leaves of crop plants are damaged when some gaseous pollutants enter the pores of the leaf. Chronic exposure of the leaves to air pollutants can break down the waxy coating that helps prevent excessive water loss and leads to damage from diseases, pests, drought and frost. Such exposure interferes with photosynthesis and plant growth, reduces nutrient uptake and causes

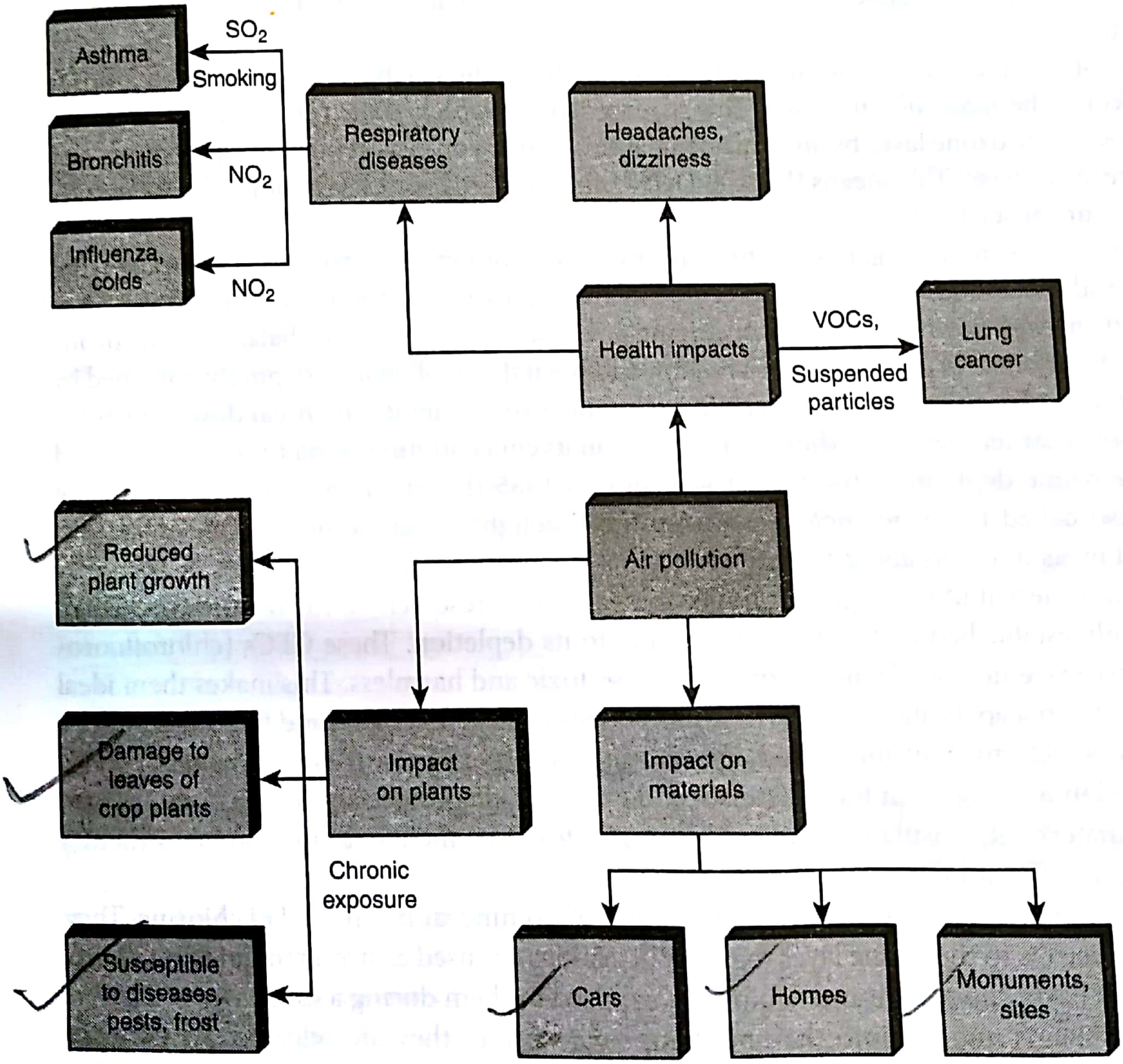


Fig. 5.2 Impact of air pollution

the leaves to turn yellow, brown or drop off altogether. At higher concentrations of sulphur dioxide, most of the flower buds become stiff and hard. They eventually fall off from the plants, as they are unable to flower.

Effects of Air Pollution on Materials

Every year, air pollutants cause damage worth billions of rupees. Air pollutants break down the exterior paint on cars and houses. They have discoloured irreplaceable monuments, historic buildings, marble statues, and other heritage and natural beauty sites.

Effects of Air Pollution on the Stratosphere

The upper stratosphere consists of considerable amounts of ozone, which works as an effective screen for UV light. This region, called the *ozone layer*, extends up to 60 km above the surface of the earth; it is, however, most dense in the region between 20 and 25 km from the earth's surface. The ozone layer does not consist solely of ozone, but also has other common atmospheric gases. In the densest portion, there is only 1 ozone molecule in 100,000 gas molecules. Therefore, even small changes to ozone concentration can produce dramatic effects on the living organisms on earth.

The total amount of ozone in a 'column' of air from the earth's surface up to an altitude of 50 km is the *total column ozone*. This is recorded in *Dobson Units (DU)*, a measure of the thickness of the ozone layer by an equivalent layer of pure ozone gas at normal temperature and pressure at sea level. This means that 100 DU = 1 mm of pure ozone gas at normal temperature and pressure at sea level.

Ozone is a form of oxygen with three atoms instead of two. It is produced naturally from the photodissociation of oxygen molecules in the atmosphere. The ozone, thus formed, is constantly broken down by naturally occurring processes that maintain its balance in the ozone layer. In the absence of pollutants, the creation and breakdown of ozone are purely governed by natural forces, but the presence of certain pollutants can accelerate the breakdown of ozone. It was known earlier that ozone shows fluctuations in its concentration, sometimes accompanied by a little ozone depletion. However, it was only in 1985 that the large scale destruction of ozone, also called the *ozone hole*, came into the limelight, when some British researchers published measurements about the ozone layer.

Soon after these findings, a greater impetus was given to research on the ozone layer, which convincingly established that CFCs were leading to its depletion. These CFCs (chlorofluorocarbons) are extremely stable, non-flammable, non-toxic and harmless. This makes them ideal for many industrial applications like aerosols, air-conditioners, refrigerators and fire extinguishers. Many cans, which give out foams and sprays, use CFCs (perfumes, room fresheners). CFCs are also used in making foam for mattresses and cushions, disposable styrofoam cups, glasses, packaging material for insulation and cold storage. However, their stability also gives them a long life-span in the atmosphere.

Halons are similar in structure to CFCs but contain bromine atoms instead of chlorine. They are more dangerous to the ozone layer than CFCs. Halons are used as fire-extinguishing agents as they do not harm the people and equipment exposed to them during a fire.

CFCs and halons migrate into the upper atmosphere after they are released. As they are heavier than air they have to be carried by air currents up to a point just above the lower atmosphere and then they slowly diffuse into the upper atmosphere. This is a slow process and can take as long as five to fifteen years. In the stratosphere, unfiltered UV radiation severs the chemical bonds, releasing chlorine from the rest of the CFC. This attacks the ozone molecule, resulting in its splitting into an oxygen molecule and an oxygen atom.

Despite the fact that CFCs are evenly distributed over the globe, ozone depletion is especially pronounced over the South Pole, due to the extreme weather conditions in the Antarctic atmosphere. The presence of ice crystals makes the Cl–O bonding easier. The ozone layer over countries like Australia, New Zealand, South Africa and parts of South America is also depleted.

India signed the Montreal Protocol in 1992, which aimed at controlling the production and consumption of ozone depleting substances. In fact, the Montreal Protocol was set up as an example of a successful international agreement—its extensive adoption is resulting in a progressive recovery of the ozone layer.

Ozone Depletion: What Does it Do?

KC-12-NC

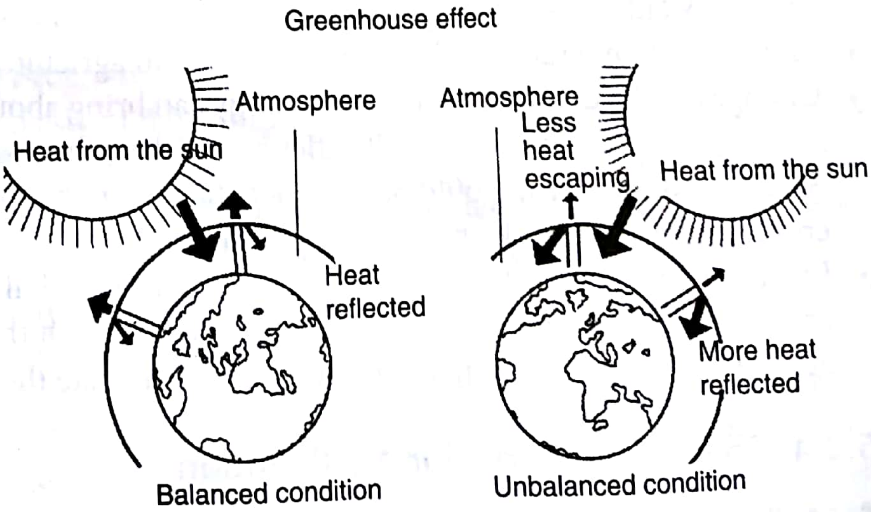
Changes in the ozone layer (Fig. 5.3) have serious implications for humans.

Effects on human health: Sunburn, cataract, ageing of the skin and skin cancer are caused by increased UV radiation. It weakens the immune system by suppressing the body's resistance to certain infections like measles, chickenpox and other viral diseases that elicit rash and parasitic diseases such as malaria introduced through the skin.

Food production: UV radiation affects the ability of plants to capture light energy during photosynthesis. This reduces the nutrient content and growth potential of plants; this is especially true in the case of legumes and cabbage.

Phyto- and *zooplankton* are damaged by UV radiation. In zooplankton (microscopic animals), the breeding period is shortened by changes in radiation. As plankton form the basis of the marine food chain, any change in their number and species composition influences fish and shellfish production.

Effect on climate: Atmospheric changes induced by pollution contribute to global warming, a phenomenon caused by the increase in concentration of certain gases like carbon dioxide, nitrogen oxides, methane and CFCs. Observations of the earth have shown beyond doubt that atmospheric constituents like water vapour, carbon dioxide, methane, nitrogen oxides and CFCs trap heat in the form of infra red (IR) radiation near the earth's surface. This is known as the greenhouse effect. The phenomenon is similar to what happens in a greenhouse. The glass in a greenhouse allows solar radiation to enter, which is absorbed by the objects inside. These objects radiate heat in the form of terrestrial radiation, which does not pass out through the glass. The heat



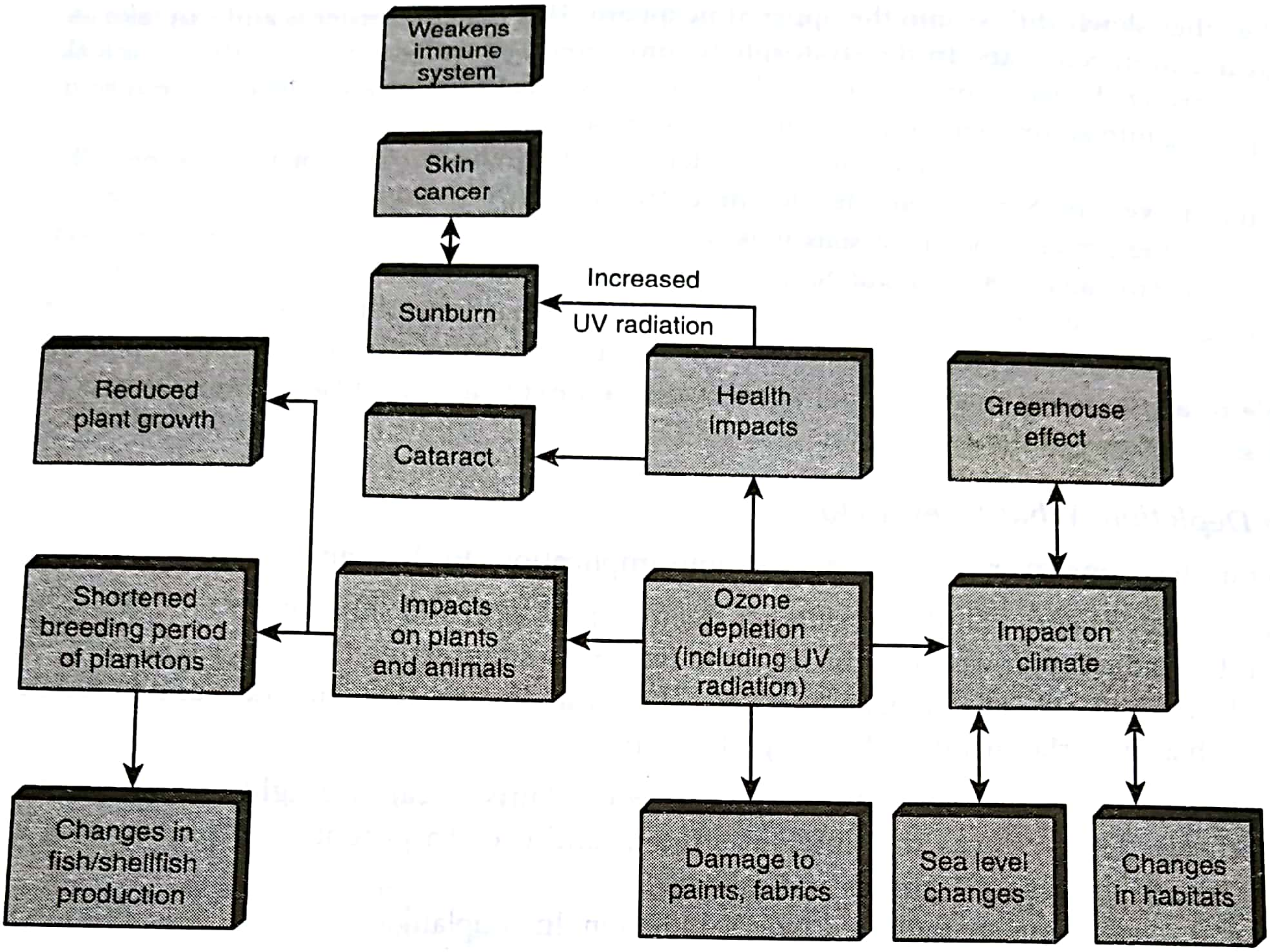


Fig. 5.3 Impact of ozone depletion

is, therefore, trapped in the greenhouse, increasing the temperature inside and ensuring the luxuriant growth of plants. There could be several adverse effects of global warming.

- With a warmer earth, the polar ice caps will melt causing a rise in ocean levels and flooding of coastal areas.
- In countries like Bangladesh and Maldives, this would be catastrophic. If the sea level rises by 3 m, Maldives will disappear completely beneath the waves.
- The rise in temperature will bring about a fall in agricultural produce.
- Changes in the distribution of solar energy can bring about changes in habitat. A previously productive agricultural area will suffer severe droughts, while rains will fall in locations that were once deserts. This could bring about changes in the species of natural plants, agricultural crops, insects, livestock and microorganisms.
- In the polar regions, temperature rise caused by global warming would have disastrous effects. Vast quantities of methane are trapped beneath the frozen soil of Alaska. When the permafrost melts, the methane released can accelerate the process of global warming.

Ans ②

5.2.4 Control Measures for Air Pollution

Air pollution can be controlled by two fundamental approaches—preventive techniques and effluent control.

① CNG

② NAMP → Naton Air qualit monit [illegible]

One of the effective means of controlling air pollution is to have proper equipment in place. This includes devices for removal of pollutants from the flue gases through scrubbers, closed-collection recovery systems (through which it is possible to collect the pollutants before they escape), the use of dry and wet collectors, filters and electrostatic precipitators.

Building higher smoke stacks facilitates the discharge of pollutants as far away from the ground as possible. Industries should be carefully located in order to minimise the effects of pollution after considering the topography and wind directions. The substitution of raw materials that cause more pollution with those that cause less pollution will also help.

Air Pollution in India

Vehicle and industry emissions are the main causes of pollution in the cities of India. The use of cleaner fuels such as Compressed Natural Gas (CNG) in Delhi and other measures such as banning old vehicles in some cities, improving traffic management, implementing the emission standards of Bharat Stage 2 (Euro 2) for vehicles and introducing improved vehicular technology in the form of Bharat Stage 3 vehicles has seen a decline in the levels of NO_2, SO_2 and CO. On the other hand, the exponential increase in the number of vehicles has meant that the Respirable Suspended Particulate Matter levels exceed the prescribed National Ambient Air Quality Standards (NAAQS) in residential areas in many cities such as Lucknow, Faridabad, Mumbai, Bangalore and Delhi (CPCB 2007).

CASE STUDY 2

Excessive exposure to sulphur dioxide and suspended particulate matter (SPM) was the main cause of the Taj Mahal's 'marble cancer'—a fungal growth that corroded its surface giving it a yellowish tinge. MC Mehta, an environmental lawyer, filed a public interest litigation (PIL) in 1984 expressing concern over the havoc the polluting units in Agra were wreaking on the Taj Mahal. Twelve years later, the Supreme Court ordered 292 industries in the vicinity to either adopt pollution control measures or to shut down. It also made it mandatory for these units to either switch over to eco-friendly fuels like natural gas or shift out of the area.

Air quality monitoring

The CPCB is executing a nation-wide programme of air quality monitoring known as the National Air Quality Monitoring Programme (NAMP). This programme aims to determine the present air quality status and trends, and to control and regulate pollution from industries and other sources to meet the ambient air quality standards. The NAMP provides background air quality data that is required for industrial siting and town planning. The NAMP has an extensive network of 342 operating stations across the country. Under this programme, four air pollutants, sulphur dioxide (SO_2), oxides of nitrogen such as NO_2, suspended particulate matter (SPM) and respirable suspended particulate matter (RSPM/PM10) have been identified for regular monitoring at all the locations. Monitoring is carried out for 24 hours, twice a week, resulting in 104 observations annually. The CPCB liaises with other agencies such as the State Pollution Control Boards, Pollution Control Committees and the National Envrionmental Engineering Research Institute, Nagpur, to ensure robust and consistent air quality data from all the monitoring stations.

Table 5.2 Air quality data

Pollutant ($\mu g/m^3$)	Time weighted average	Concentration in ambient air	
		Industrial, residential and rural	Ecologically sensitive
SO_2	Annual	50	20
NO_2	Annual	40	30
CO	8 hours	2	2
PM10	Annual	60	60
PM2.5	Annual	40	40

Source: CPCB 2008

Legal aspects of air pollution control in India

The Air (Prevention and Control of Pollution) Act was legislated in 1981. The Act provided for the prevention, control and abatement of air pollution. In the areas notified under this Act, no industrial pollution-causing activity could come up without the permission of the concerned CPCB. But this Act was not strong enough to play a precautionary or corrective role. After the Bhopal disaster, a more comprehensive Environment Protection Act (EPA) was passed in 1986. This Act, for the first time, conferred enforcement agencies with necessary punitive powers to restrict any activity that could harm the environment. To regulate vehicular pollution, the Central Motor Vehicles Act of 1939 was amended in 1989. Following this amendment, the exhaust emission rules for vehicle owners were notified in 1990 and the mass emission standards for vehicle manufacturers were enforced in 1991 for the first time. The mass emission norms were further revised for 2000. More recently, all transport vehicles require a Pollution Under Control (PUC) certificate, renewable each year after the first two years of a new vehicle registration. In 2003, the National Auto Fuel Policy was announced with an implementation schedule of a phased programme for introducing Euro 2 to 4 emission fuel regulations by 2010.

5.3 WATER POLLUTION

> 'Our liquid planet glows like a soft blue sapphire in the hard-edged darkness of space. There is nothing else like it in the solar system. It is because of water.'
>
> —*John Todd*

Water is the essential element that makes life on earth possible. Without water there would be no life. We usually take water for granted. It flows from taps when they are turned on; most of us are able to bathe when we want to, swim when we choose to and water our gardens. Like good health, we take water for granted when we have it.

Although 71% of the earth's surface is covered by water, only a tiny fraction of this is available as freshwater. About 97% of the total water available on earth is found in the oceans and is too salty for drinking or irrigation. The remaining 3% is fresh water. Of this, 2.997% is locked in ice caps and glaciers. Thus, only 0.003% of the earth's total volume of water is easily available to us as soil moisture, groundwater, water vapour and water in lakes, streams, rivers and wetlands.

In short, if the world's water supply were only 100 litres, our usable supply of freshwater would be only about 0.003 litres (half a teaspoon!). This makes water a very precious resource. By the middle of this century, almost twice as many people will be trying to share the same amount of freshwater the earth has today. With water wars within and between countries already underway, the access to water resources has become an important factor in sustaining the overall development of any nations' economy.

Water availability on the planet: The water found in streams, rivers, lakes, wetlands and artificial reservoirs is called surface water. Water that percolates into the ground and fills the pores in soil and rock is called groundwater. Porous water-saturated layers of sand, gravel or bedrock through which ground water flows are called aquifers. Most aquifers are replenished naturally by rainfall that percolates downward through the soil and rock. This process is called natural recharge. If the withdrawal rate of an aquifer exceeds its natural recharge rate, the water table is lowered. Any pollutant that is discharged onto the land above is also pulled into the aquifer and pollutes the groundwater, resulting in polluted water in nearby wells.

Water availability in India: India receives most of her rainfall during the months of June to September due to seasonal winds and temperature differences between the land and the sea. These winds blow from opposite directions in the different seasons. They blow into India from the surrounding oceans in summer and blow out from the subcontinent to the oceans in winter. The monsoon in India is usually reasonably stable but varies geographically. In some years, the commencement of the rains may be delayed considerably over the entire country or a part of it. The rains may also terminate earlier than usual. They may be heavier than usual over one part than over another. All these may cause local floods or drought. However, in India even areas that receive adequate rainfall during the monsoon suffer from water shortage in the post-monsoon period due to the lack of adequate storage facilities.

When the quality or composition of water changes directly or indirectly as a result of human activities such that it becomes unfit for any purpose it is said to be polluted.

Point sources of pollution: When a source of pollution can be readily identified because it has a definite source and place where it enters the water, it is said to come from a point source; for example, municipal and industrial discharge pipes.

When a source of pollution cannot be readily identified, such as agricultural run-off or acid rain, they are said to be non-point sources or diffused sources of pollution (Fig. 5.4).

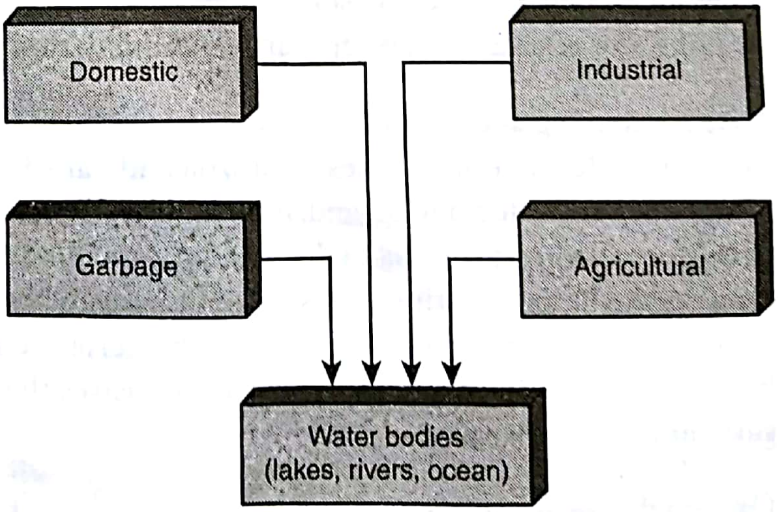


Fig. 5.4 Point sources of pollution

5.3.1 Causes of Water Pollution

There are several classes of common water pollutants (Fig. 5.5). These are:

- disease causing agents (pathogens),
- oxygen depleting waste,
- inorganic plant nutrients,
- water soluble inorganic chemicals,
- organic chemicals,

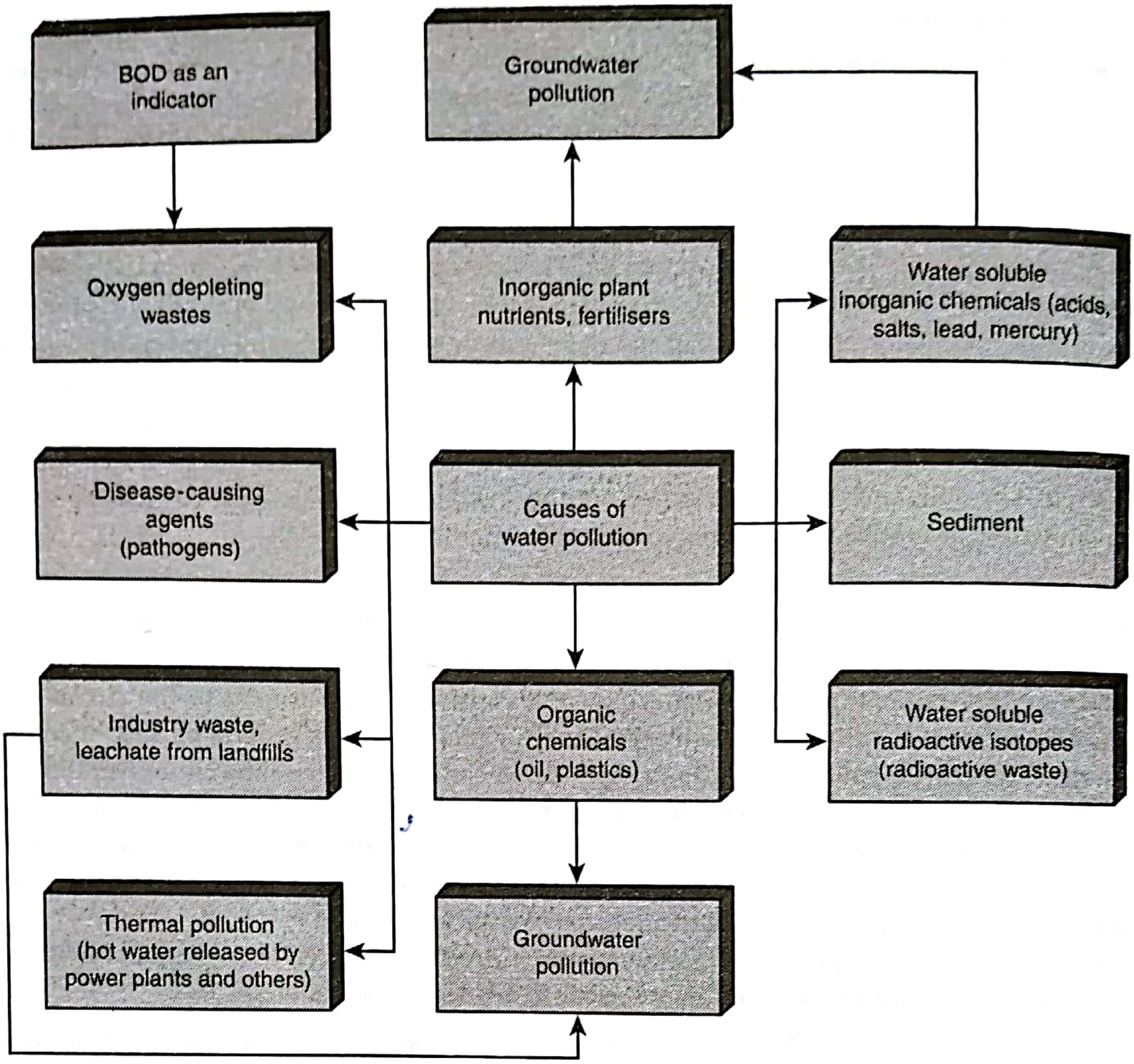

BOD as an indicator
Groundwater pollution
Oxygen depleting wastes
Inorganic plant nutrients, fertilisers
Water soluble inorganic chemicals (acids, salts, lead, mercury)
Disease-causing agents (pathogens)
Causes of water pollution
Sediment
Industry waste, leachate from landfills
Organic chemicals (oil, plastics)
Water soluble radioactive isotopes (radioactive waste)
Thermal pollution (hot water released by power plants and others)
Groundwater pollution

Fig. 5.5 Causes of water pollution

- sediment of suspended matter,
- water soluble radioactive isotopes, and
- hot water released by power plants and industries.

① Disease causing agents (Pathogens)

These include bacteria, viruses, protozoa and parasitic worms that enter water from domestic sewage and untreated human and animal waste. Human waste contains concentrated populations of coliform bacteria such as *Escherichia coli* and *Streptococcus faecalis*. These bacteria normally grow in the large intestine of the human body, where they are responsible for digestion and for the production of vitamin K. These bacteria are not harmful in low numbers. However, large amounts of human waste in water increases the number of these bacteria, which causes gastrointestinal diseases.

② Oxygen depleting waste

These are organic wastes that can be decomposed by aerobic (oxygen requiring) bacteria; large populations of bacteria use up the oxygen present in the water in order to degrade these wastes.

This degrades the water quality as it uses up the oxygen available for other aquatic life such as fish. The amount of oxygen required to break down a certain amount of organic matter is called the biological oxygen demand (BOD). The amount of BOD in water is an indicator of the level of pollution. If too much organic matter is added to water, all the available oxygen is used up. This causes fish and other forms of oxygen-dependent aquatic life to die. Thus, anaerobic bacteria (those that do not require oxygen) begin to break down the waste. Their anaerobic respiration produces chemicals that have a foul odour and an unpleasant taste, which are harmful to human health.

③ Inorganic plant nutrients

These include water-soluble nitrates and phosphates such as those found in fertilisers. The quantity of fertilisers applied in a field is often many times more than is actually required by the plants. Run-off carries excess fertilisers into nearby water bodies, causing high levels of plant nutrients (eutrophication) which promote the excessive growth of algae and other aquatic plants. This may interfere with the use of the water by clogging up water intake pipes, changing the taste and smell of the water and causing a build up of organic matter. As the organic matter decays, the oxygen levels decrease and fish and other aquatic species die.

④ Water soluble inorganic chemicals

These are acids, salts and compounds of toxic metals such as mercury and lead. High levels of these chemicals can make the water unfit to drink, harm fish and other aquatic life, reduce crop yield and accelerate the corrosion of equipment that is in contact with this water.

⑤ Sediment of suspended matter

These are insoluble particles of soil and other solids that become suspended in water. This occurs when the soil is eroded from the land. High levels of soil particles suspended in water interfere with the penetration of sunlight. This reduces the photosynthetic activity of aquatic plants and algae, disrupting the ecological balance of the aquatic bodies. When the velocity of water in streams and rivers decreases, the suspended particles settle down at the bottom as sediments. The excessive sediments destroy the feeding and spawning grounds of fish, clog and fill lakes and artificial reservoirs.

⑥ Water soluble radioactive isotopes

These are contained in radioactive waste. They can be concentrated in various tissues and organs as they pass through food chains and food webs. The ionising radiation emitted by such isotopes can cause birth defects, cancer and genetic damage.

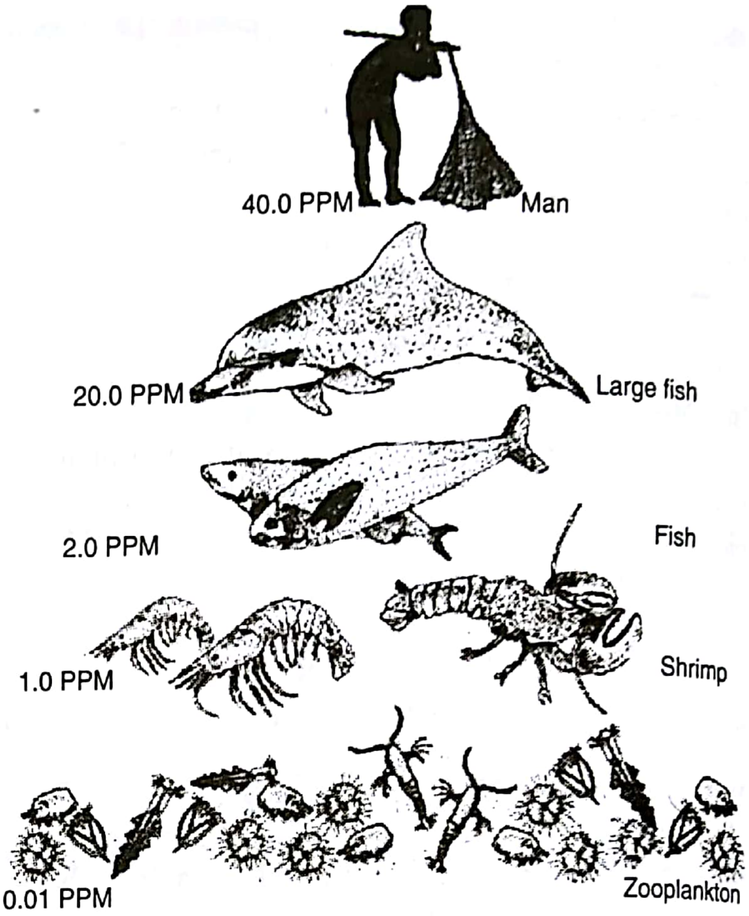
⑦ Hot water released by power plants and industries

The hot water released by power plants and industries that use large volumes of water to cool the plant, results in a rise in temperature of the local water bodies; thermal pollution occurs due to this. This warm water not only decreases the solubility of oxygen but changes the breeding cycles of various aquatic organisms.

⑧ Organic chemicals

These include oil, gasoline, plastic, pesticides, cleaning solvents, detergents and many other chemicals. These are harmful to aquatic life and human health. They enter the water directly from industrial activity, from improper handling of chemicals in industries and usually from the improper and illegal disposal of chemical wastes.

Pesticides are an example of organic chemicals that enter the water cycle through agricultural activities. The application of pesticides can cause *bioaccumulation* and *biomagnification* of harmful substances in the aquatic food chain. Pesticides enter the water cycle as run-off from agricultural areas. They are absorbed by the phytoplankton and aquatic plants. These plants are eaten by herbivorous fish, which are in turn eaten by carnivorous fish, which are eaten by water birds. At each link in the food chain, these chemicals which do not pass out of the body get accumulated (bioaccumulation) and increasingly concentrated (biomagnification).



Biomagnification along the food chain

One of the effects of accumulation of high levels of pesticides, such as DDT, is that birds lay eggs with shells that are much thinner than normal. This results in the premature breaking of these eggs, killing the immature chicks inside. Birds of prey, like hawks, eagles and other fish-eating birds, are affected by such pollution. DDT has been banned in India for agricultural use and is to be used only for malaria eradication.

Oil is another organic chemical which can enter surface water bodies in run-off from roads and parking lots. The leakage from underground tanks can also pollute groundwater. Accidental oil spills from large transport tankers at sea have been causing significant environmental damage to marine ecosystems. Oil pollution has been further discussed later in this chapter.

⑨ Groundwater pollution

While oil spills are highly visible and often get a lot of media attention, a much greater threat to human life comes when groundwater, which is used for drinking and irrigation, becomes polluted. While groundwater is easy to deplete and pollute, it gets renewed very slowly and hence must be used judiciously. Groundwater flows are slow and not turbulent; thus, the contaminants are not as effectively diluted and dispersed as in surface water. Moreover, pumping groundwater and treating it is a very slow and expensive process. It is therefore extremely essential to prevent the pollution of groundwater in the first place. Some causes of groundwater pollution are:

- urban run-off of untreated or poorly treated waste water and garbage,
- industrial waste storage located above or near aquifers,

- agricultural practices such as the application of large amounts of fertilisers and pesticides and animal feeding operations in the rural sector,
- leaks from underground storage tanks containing gasoline and other hazardous substances,
- leachate from landfills,
- poorly designed and inadequately maintained septic tanks, and
- mining waste.

CASE STUDY 3

Arsenic poisoning

Severe cases of arsenic poisoning from contaminated groundwater have been reported from West Bengal in what is known today as the worst case of groundwater pollution. According to a report in *Down to Earth* (Vol.11, No. 22), arsenic poisoning was first noticed by K C Saha, former Professor of Dermatology at the School of Tropical Medicine, Kolkata, when he began to receive patients with skin lesions that resembled the symptoms of leprosy but which was in reality not leprosy. Since all the patients were from the district of the 24 Parganas, Saha along with others began to look for the cause and found that it was arsenic toxicity. 'Arsenicosis' or arsenic toxicity develops after 2–5 years exposure to arsenic-contaminated drinking water, depending on the amount of water consumed and the arsenic concentration in the water.

Two theories have been put forth to explain this unusually high content of arsenic in the groundwater. One group of researchers suggested that the cause was natural, originating in the Himalayan headwaters of the Ganga and the Brahmaputra rivers. Other researchers stated that the cause was artificial, attributed to the high rate of groundwater extraction for irrigation development.

5.3.2 The State of India's Rivers

Indians have always had a tradition of venerating their rivers. Most rivers in India are worshipped and named after gods, goddesses or saints. Ironically, these rivers suffer from severe pollution. Urbanisation, industrialisation, excessive withdrawal of water, agricultural run-off, improper agricultural practices and various religious and social practices all contribute to river pollution in India. Every single river in India, be it the Ganga, Yamuna, Cauvery or Krishna, has its own share of problems due to pollution. Waters from the Ganga and Yamuna are drawn for irrigation through the network of canals as soon as these rivers reach the plains, reducing the amount of water that flows downstream. What flows in the river now is water from small *nullahs* and streams that carry with them sewage and industrial effluents. The residual freshwater is unable to dilute the pollutants and the rivers turn into stinking sewers. In spite of data from scientifically competent studies conducted by the CPCB, the Government has not been able to tackle this issue. Sewage and municipal effluents account for 75% of the pollution load in rivers while the remaining 25% is from industrial effluents and non-point pollution sources.

In 1985, India launched the Ganga Action plan (GAP), the largest ever river clean up operation in the country. The plan has been criticised for overspending and slow progress. GAP Phase-II in 1991 included cleaning operations for the tributaries of the Ganga—the Yamuna, Gomti and Damodar. Thus, the Yamuna Action Plan (YAP), Gomti Action Plan and Damodar Action Plan (DAP) were added.

In 1995, the National River Conservation Plan (NRCP) was launched. Under this, all the rivers in India were taken up for clean up operations. In most of these plans, attempts have been made to tap drains and divert sewage to treatment plants, before letting them out into rivers. The approved cost for the plan is Rs 772.08 crores, covering 18 rivers in 10 states, including 46 towns. The cost is borne entirely by the Central Government and the Ministry of Environment and Forests (MoEF). Under this plan, the main activities include treating the pollution load from sewer systems of towns and cities, setting up sewage treatment plants, electric crematoria and low-cost sanitation facilities, riverfront development, afforestation and solid waste management.

The biggest drawback of these river-cleaning programmes was that they failed to allocate responsibility regarding who would pay for running the treatment facilities in the long run. With the power supply being erratic and these plants being heavily dependent on power, most of these facilities lie under-utilised. Moreover, the problem of river pollution due to agricultural run-off has not been addressed in this programme.

In order to strengthen the ongoing NRCP, a new initiative called the National Ganga River Basin Authority (NGRBA) was formed in 2009. The first meeting of the NGRBA resolved to make the Ganga pollution-free by 2020. The total cost would be approximately Rs 15,000 crore, with an initial assistance of $1 billion from the World Bank. While the NGRBA applies a more holistic approach in planning, financing, monitoring and coordinating authorities for the conservation of the Ganga, only time will prove the true integrity of this plan.

5.3.3 Control Measures for Water Pollution

While the foremost necessity is prevention, setting up effluent treatment plants to treat waste can reduce the pollution load in the recipient water. The treated effluent can be reused for gardening or cooling purposes, where possible. A few years ago, a new technology called the Root Zone Process was developed by Thermax. This system involves running contaminated water through the root zones of specially designed reed beds (Fig. 5.6). The reeds, which are essentially wetland plants, have the capacity to absorb oxygen from the surrounding air through their stomatal openings. The oxygen is pushed through the porous stem of the reeds into the hollow roots where it enters the root zone and creates conditions suitable for the growth of numerous bacteria and fungi. These microorganisms oxidise impurities in the wastewater so that the water which finally comes out is clean.

5.4 SOIL POLLUTION

> **'We can no more manufacture soil with a tank of chemicals than we can invent a rain-forest or produce a single bird. We may enhance the soil by helping its processes along, but we can never recreate what we destroy. The soil is a resource for which there is no substitute.'**
>
> *—Donald Worster*

He reminds us that fertilisers are not a substitute for fertile soil.

The soil is a thin covering over the land consisting of a mixture of minerals, organic material, living organisms, air and water, that together support the growth of plant life. Several factors

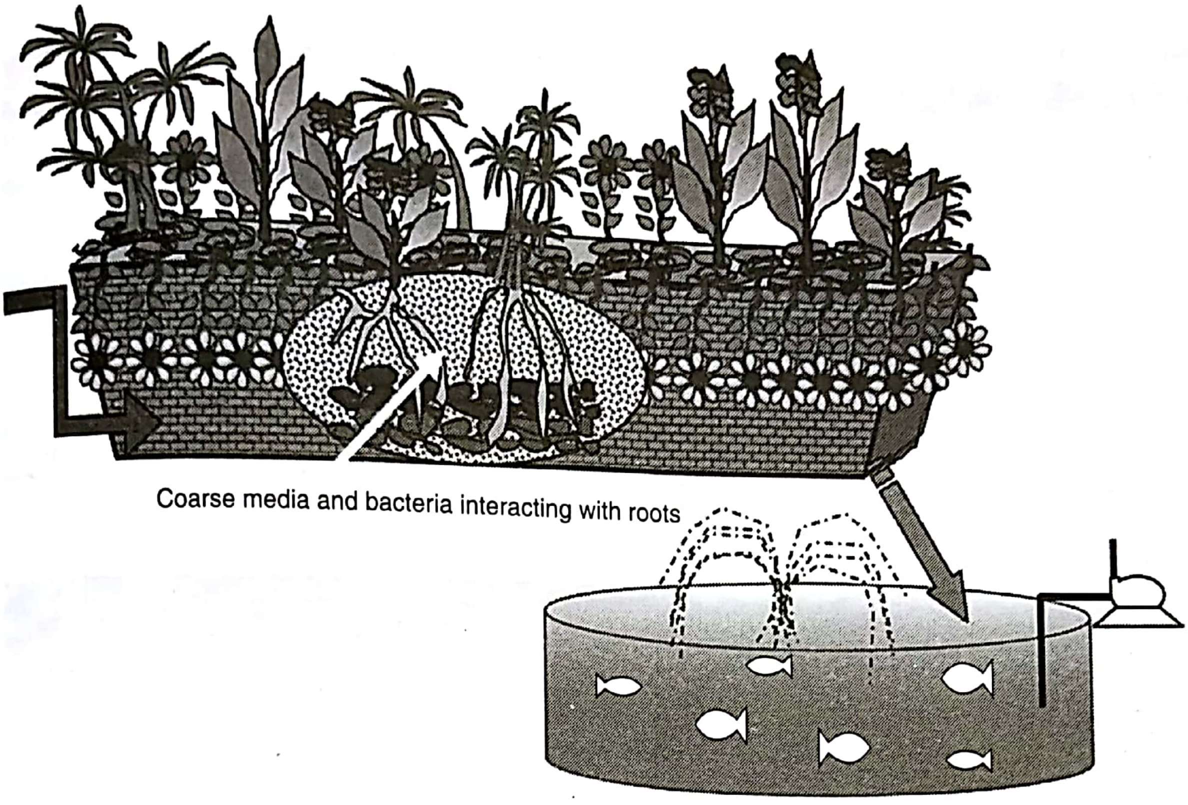


Fig. 5.6 Root zone process

contribute to the formation of soil from the parent material. This includes the mechanical weathering of rocks due to temperature changes and abrasion, wind, moving water, glaciers, chemical weathering activities and lichen. Climate and time are also important in the development of soils. In extremely dry or cold climates, soils develop very slowly, while in humid and warm climates, they develop more rapidly. Under ideal climatic conditions, soft parent material may develop into 1 cm of soil within 15 years. Under poor climatic conditions, hard parent material may require hundreds of years to develop into soil.

Mature soils are arranged in a series of zones called *soil horizons*. Each horizon has a distinct texture and composition that varies with the type of soil. A cross-sectional view of the horizons in a soil is called a *soil profile*.

The top layer or surface litter layer, called the *O-horizon*, consists mostly of freshly fallen and partially decomposed leaves, twigs, animal waste, fungi and other organic materials. Normally, it is brown or black.

The uppermost layer of the soil, called the *A-horizon*, consists of partially-decomposed organic matter (humus) and some inorganic mineral particles. It is usually darker and looser than the deeper layers. The roots of most plants are found in these two upper layers. As long as these layers are anchored by vegetation, the soil stores water and releases it in a trickle throughout the year instead of in a force like a flood. These two top layers also contain a large amount of bacteria, fungi, earthworms and other small insects, which form complex food webs in the soil, help recycle soil nutrients and contribute to soil fertility.

The *B-horizon*, often called the subsoil, contains less organic material and fewer organisms than the A horizon. The area below the subsoil is called the *C-horizon* and consists of weathered parent material. This parent material does not contain any organic materials. The chemical

Table 5.3 Area treatment

Purpose	Treatment measure	Effect
Reduces the impact of raindrops on the soil	Develop vegetative cover on non-arable land	Minimum disturbance and displacement of soil particles
Infiltration of water where it falls	Apply water infiltration measures on the area	In situ soil and moisture conservation
Minimum surface run-off	Store surplus rainwater by constructing bunds and ponds in the area	Increased soil moisture in the area, facilitates groundwater recharge
Ridge to valley sequencing	Treat the upper catchment first and then proceed towards the outlet	Economically viable, less risk of damage and longer life of structures of the lower catchments

Table 5.4 Drainage-line treatment

Purpose	Treatment measure	Effect
Stop further deepening of gullies and retain sediment run-off	Plug the gullies at formation	Stops erosion, recharges groundwater at the upper level
Reduce run-off velocity, pass cleaner water to the downstream side	Create temporary barriers in nullahs	Delayed flow and increased groundwater recharge
Low construction cost	Use local material and skills for constructing structures	Structures are locally maintained

composition of the C-horizon helps to determine the pH of the soil and also influences the soil's rate of water absorption and retention.

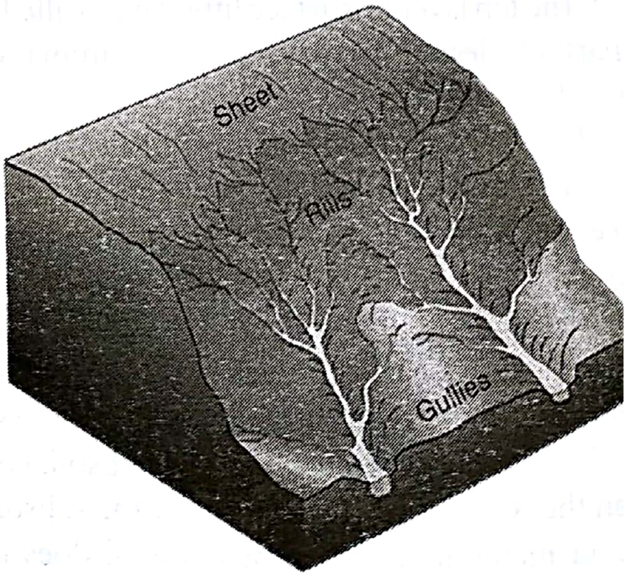
Soils vary in their content of clay (very fine particles), silt (fine particles), sand (medium-sized particles) and gravel (coarse to very coarse particles). The relative amounts of the different sizes and types of mineral particles determine the soil texture. Soils with approximately equal mixtures of clay, sand, silt and humus are called loams.

5.4.1 Causes of Soil Degradation

Erosion

Soil erosion can be defined as the movement of surface litter and topsoil from one place to another. While erosion is a natural process, often caused by wind and flowing water, it is greatly accelerated by human activities such as farming, construction, over-grazing by livestock, burning of grass cover and deforestation.

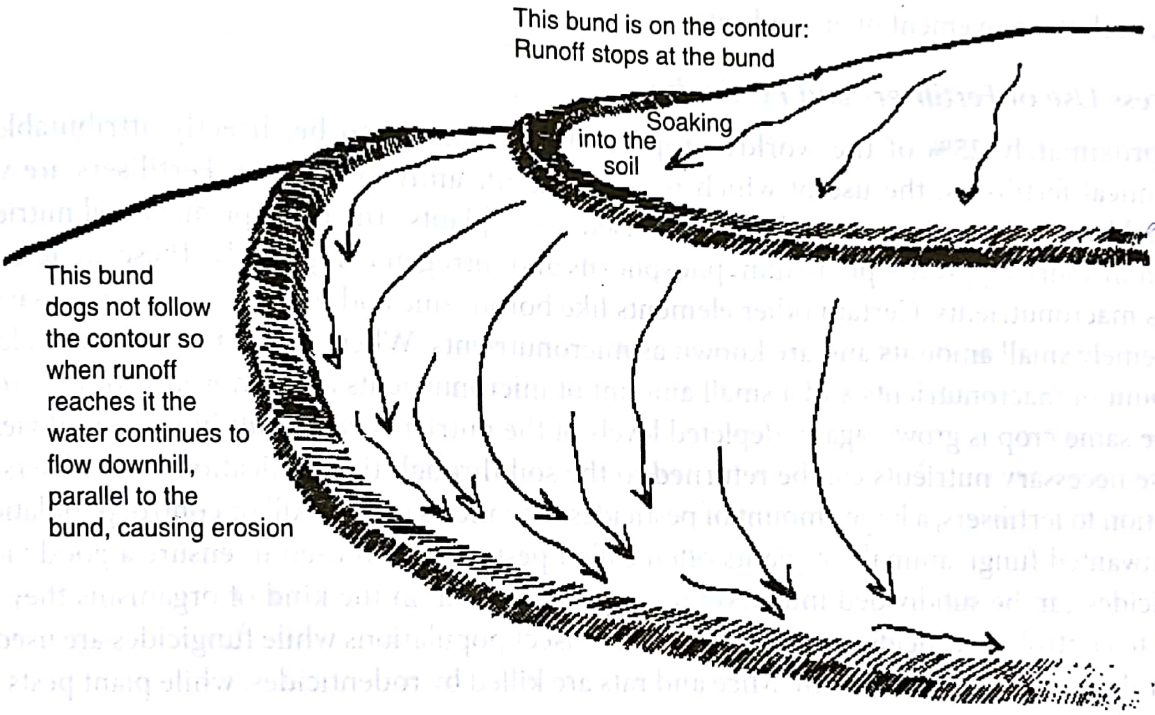
The loss of the topsoil makes soil less fertile and reduces its water-holding capacity. The topsoil, which is washed away, also contributes to water pollution by clogging lakes and increasing the turbidity of the water, ultimately leading to



the loss of aquatic life. For one inch of topsoil to be formed, it normally requires 200–1000 years, depending on the climate and soil type. Thus, if the topsoil erodes faster than it is formed, the soil becomes a non-renewable resource.

Therefore, it is essential that proper soil conservation measures are used to minimise loss of the topsoil. Several techniques can protect the soil from erosion. Today, both water and soil are conserved through integrated treatment methods. The two types of treatment generally used are—area treatment, which involves treating the land and drainage-line treatment, which involves treating the natural water courses (nullahs).

Continuous contour trenches can be used to enhance the infiltration of water, reduce the run-off and check soil erosion. These are actually shallow trenches dug across the slope of the land and along the contour lines, for the purpose of soil and water conservation. They are most effective on gentle slopes and in areas of low to medium rainfall. These *bunds* are stabilised by fast-growing tree species and grasses. In areas with steep slopes where *bunds* are not possible, continuous contour benches (CCBs) made of stones are used for the same purpose.

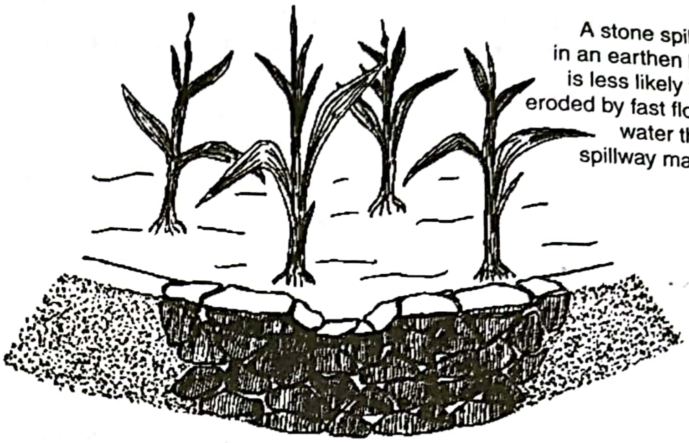

This bund is on the contour:
Runoff stops at the bund
Soaking into the soil
This bund dogs not follow the contour so when runoff reaches it the water continues to flow downhill, parallel to the bund, causing erosion

Gradonies can also be used to convert wastelands into agricultural lands. In this, narrow trenches with *bunds* on the downstream side are built along contours in the upper reaches of the catchment to collect run-off and to conserve moisture from the trees or tree crops. The area between the two *bunds* is used for cultivating crops after development of fertile soil cover.

Some of the ways in which this can be achieved are:

- Live check-dams, in which barriers are created by planting grass, shrubs and trees across the *gullies*.
- A bund constructed out of stones across the stream can also be used for conserving soil and water.
- An earthen check-bund constructed out of local soil across the stream to check soil erosion and the flow of water.

- A gabion structure, which is a bund constructed of stone and wrapped in galvanised chain link.
- A gabion structure has a one-inch-thick, impervious wall of ferrocement at the centre of the structure, which goes below the ground level up to the hard strata. This ferrocement partition, supported by the gabion portion, is able to retain water and withstand the force of the run-off water.



A stone spillway in an earthen bund is less likely to be eroded by fast flowing water than a spillway made of earth

- A *bandhara* is an underground structure across a *nullah* bed that functions as a barrier to check the movement of groundwater.

Excess Use of Fertilisers and Pesticides

Approximately 25% of the world's crop yield is estimated to be directly attributable to chemical fertilisers, the use of which is rising significantly every year. Fertilisers are very valuable, as they replace the soil nutrients used up by plants. The three primary soil nutrients often in short supply are potassium, phosphorus and nitrogen compounds. These are referred to as macronutrients. Certain other elements like boron, zinc and manganese are necessary in extremely small amounts and are known as micronutrients. When crops are harvested, a large amount of macronutrients and a small amount of micronutrients are removed with the crops. If the same crop is grown again, depleted levels of the nutrients can result in decreased yields. These necessary nutrients can be returned to the soil through the application of fertilisers. In addition to fertilisers, a large amount of pesticides (chemicals used to kill or control populations of unwanted fungi, animals or plants often called pests) are also used to ensure a good yield. Pesticides can be subdivided into several categories, based on the kind of organisms they are used to control. Insecticides are used to control insect populations while fungicides are used to control unwanted fungal growth. Mice and rats are killed by rodenticides, while plant pests are controlled by herbicides.

Pesticides not only kill the pests but also a large variety of living things, including humans. They may be persistent or non-persistent. Persistent pesticides, once applied, are effective for a long time. However, as they do not break down easily, they tend to accumulate in the soil and in the bodies of animals in the food chain, causing bioaccumulation and biomagnification (or bioamplification).

For example, DDT, one of the first synthetic organic insecticides to be used, was thought to be the perfect insecticide. During the first ten years of its use (1942–1952), DDT is estimated to have saved about five million lives primarily because of its use in controlling disease carrying mosquitoes. However, after a period of use, many mosquitoes and insects became resistant to DDT, making it ineffective. In temperate regions, DDT has a half-life (the amount of time required for half of the chemical to decompose) of 10–15 years. This means that if 100 kg of DDT were to be sprayed over an area, 50 kg would still be present in the area 10–15 years later.

The half-life of DDT varies according to the soil type, temperature, kind of soil organisms present, and other factors. In tropical parts of the world, the half-life may be as short as 6 months. The use of DDT has been banned in some countries. However, India still permits the use of DDT, although only for purposes of mosquito control.

Other problems associated with insecticides are the ability of insect populations to become resistant to them, thus rendering them useless in a couple of generations. Most pesticides kill beneficial as well as pest species. They kill the predator as well as the parasitic insects that control the pests. Thus, the pest species increase rapidly following the use of a pesticide as there are no natural checks to their population growth. The short-term and long-term health effects on the persons using the pesticide and the public that consumes the food grown by using the pesticides are also major concerns. Exposure to small quantities of pesticides over several years can cause mutations or produce cancers.

If pesticides have so many drawbacks, why·are they used so extensively and what are the substitutes for them?

There are three main reasons for the use of pesticides:

(i) The use of pesticides in the short term has increased the amount of food that can be grown in many parts of the world as the damage by pests is decreased.

(ii) Its extensive use is based on an economic consideration. The increased yield more than compensates the farmer for the cost of pesticides.

(iii) Current health problems, especially in developing countries, due to mosquitoes are impossible to control without insecticides.

Farmers are now increasingly opting to replace chemical fertilisers and use different methods of controlling pests without affecting their yield. Thus, several different approaches that have slightly varying and overlapping goals have been developed as alternatives to using fertilisers and pesticides. Alternative agriculture is the broadest term that includes all non-traditional agricultural methods and encompasses sustainable agriculture, organic agriculture, alternative uses of traditional crops and alternative methods for raising crops.

Sustainable agriculture advocates the use of methods to produce adequate safe food in an economically viable manner, while maintaining the state of the ecosystem. Organic agriculture advocates avoiding the use of chemical fertilisers and pesticides. A wide variety of techniques can be used to reduce this negative impact of agriculture. Leaving crop residue on the soil and incorporating it into the soil reduces erosion and increases soil organic matter. The introduction of organic matter into the soil also makes compaction less likely. Crop rotation is an effective way to enhance soil fertility, reduce erosion and control pests. There have been arguments both for and against organic farming. Critics argue that organic farming cannot produce the amount of food required for today's population and it is economically viable only under certain conditions. However, supporters of organic farming feel that if the hidden costs of soil erosion and pollution are taken into account, it is a viable approach. Besides, organic farmers do not have to spend money on fertilisers and pesticides and also get a premium price for their products, thus making it financially viable for them.

Another way to reduce the impact is by *integrated pest management (IPM)*. This is a technique that uses a complete understanding of all the ecological aspects of a crop and the particular pests to which it is susceptible to establish pest control strategies that use no or few pesticides.

IPM promotes the use of biopesticides. These are derived from three sources—microbial, botanical and biochemical. Microbial pesticides are microorganisms such as bacteria, fungi, viruses or protozoa that fight pests through a variety of ways. They produce toxins specific to the pests and cause diseases in them. Biochemical pesticides contain several chemicals that affect the reproductive and digestive mechanisms of the pests. The most commonly used biopesticides are *Bacillus thuringiensis (Bt)*, neem (*Azadirachta indica*) and trichogramma. Although they are available in the market, they are yet to become market favorites.

Excess Salts and Water

Irrigated lands can produce higher crop yields than those that only use rainwater. However, this has its own set of ill-effects. Irrigation water contains dissolved salts and in dry climates much of the water in the saline solution evaporates leaving its salts, such as sodium chloride, in the topsoil. The accumulation of these salts is called salinisation, which can stunt plant growth, lower crop yield and eventually kill the crop and render the land useless for agriculture. These salts can be flushed out of the soil by using more water. This practice, however, increases the cost of crop production and also wastes enormous amounts of water. Flushing out salts can also make the downstream irrigation water saltier.

Thus, in the long run it is better to adopt sustainable farming practices to prevent the degradation of soil.

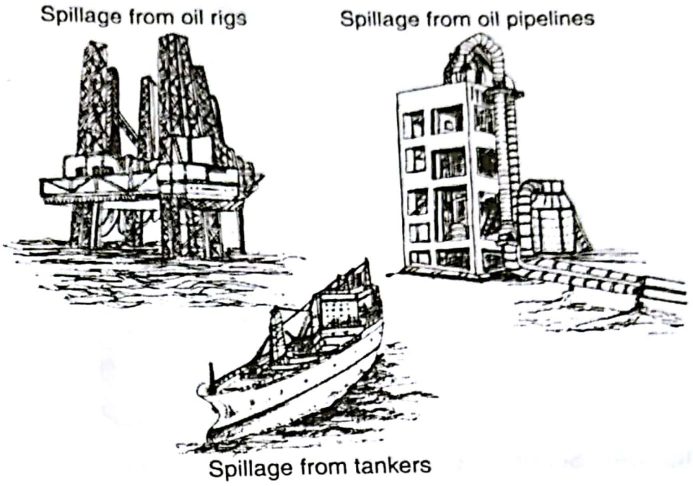
5.5 MARINE POLLUTION

Marine pollution can be defined as the introduction of substances to the marine environment directly or indirectly by humans resulting in adverse effects such as hazards to human health, obstruction of marine activities and lowering of the quality of sea water. While the causes of marine pollution may be similar to those of general water pollution, there are some very specific causes that pollute marine waters.

- The most obvious input of waste is through pipes directly discharging waste into the sea. Very often, municipal waste and sewage from residences and hotels in coastal towns are directly discharged into the sea.
- Pesticides and fertilisers from agriculture, which are washed off the land by rain, enter water courses and eventually reach the sea.
- Petroleum and oils washed off from roads normally enter the sewage system but storm water overflows carry these materials into rivers and eventually into the seas.
- Ship accidents and accidental spillages at sea can be very damaging to the marine environment. Shipping channels in estuaries and at the entrances to ports often require frequent dredging to keep them open. This dredged material that may contain heavy metals and other contaminants is often dumped out at sea.
- Offshore oil exploration and extraction also pollute the seawater to a large extent.

5.5.1 Pollution Due to Organic Wastes

The amount of oxygen dissolved in the water is vital for plants and animals living in it. Waste, which directly or indirectly affects the oxygen concentration, plays an important role in determining the quality of water. Normally, the greatest volume of waste discharged to water courses, estuaries and the sea is sewage, which is primarily organic in nature and is degraded



by bacterial activity. Using the oxygen present in the water, these wastes are broken down into stable inorganic compounds. However, as a result of this bacterial activity, the oxygen concentration in the water is reduced. When the oxygen concentration falls below 1.5 mg/l, the rate of aerobic oxidation is reduced and replaced by anaerobic bacteria that can oxidise the organic molecules without the use of oxygen. This results in end products such as hydrogen sulphide, ammonia and methane which are toxic to many organisms. This process results in the formation of an anoxic zone which is low in its oxygen content; from which most life disappears except for anaerobic bacteria, fungi, yeast and some protozoa; and renders the water foul-smelling.

Control Measures

One way of reducing the pollution load on marine waters is by introducing sewage treatment plants. This will reduce the biological oxygen demand (BOD) of the final product before it is discharged to the receiving waters. Various stages of treatment such as primary, secondary or advanced can be used, depending on the quality of the effluent to be treated.

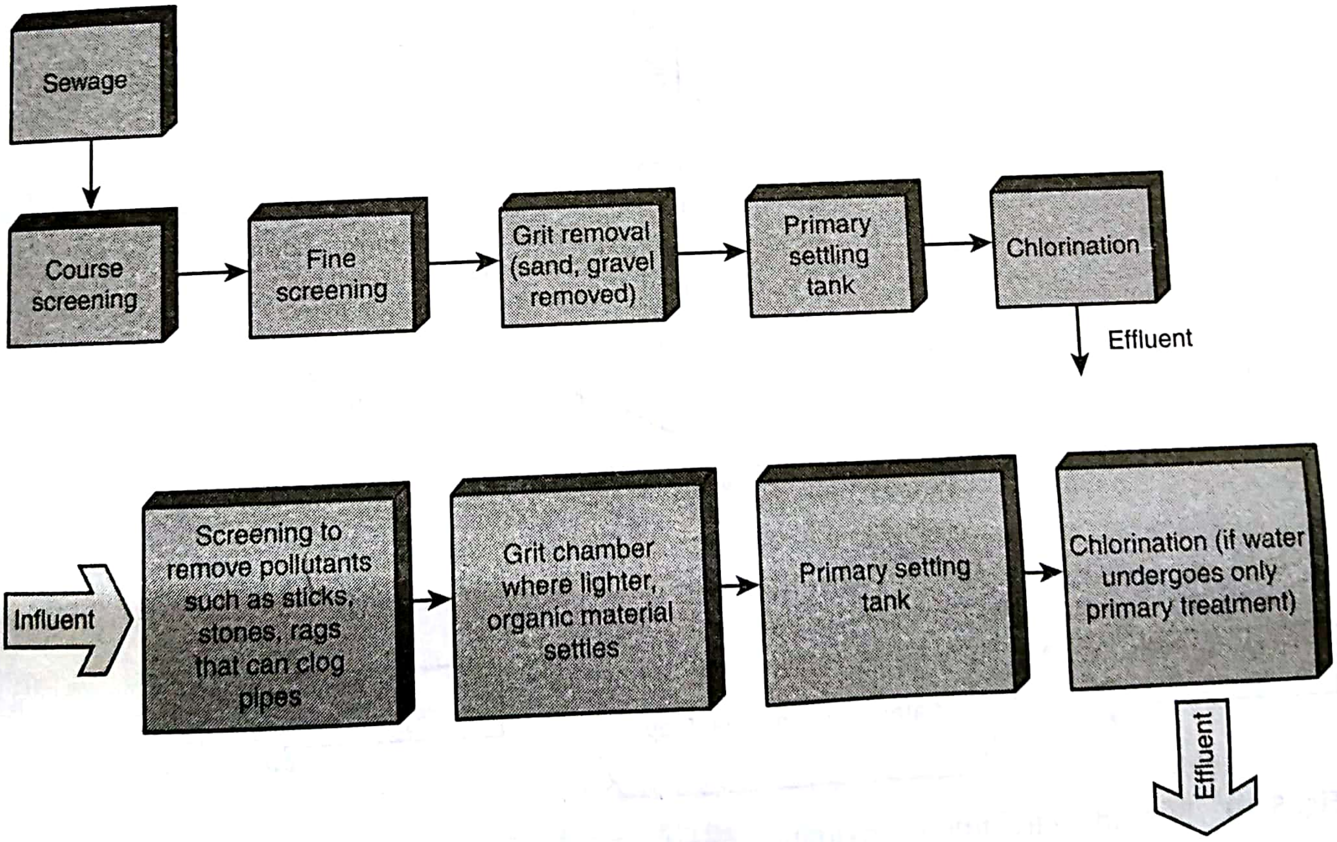

Sewage
Course screening
Fine screening
Grit removal (sand, gravel removed)
Primary settling tank
Chlorination
Effluent
Influent
Screening to remove pollutants such as sticks, stones, rags that can clog pipes
Grit chamber where lighter, organic material settles
Primary setting tank
Chlorination (if water undergoes only primary treatment)
Effluent

Fig. 5.7 Primary treatment

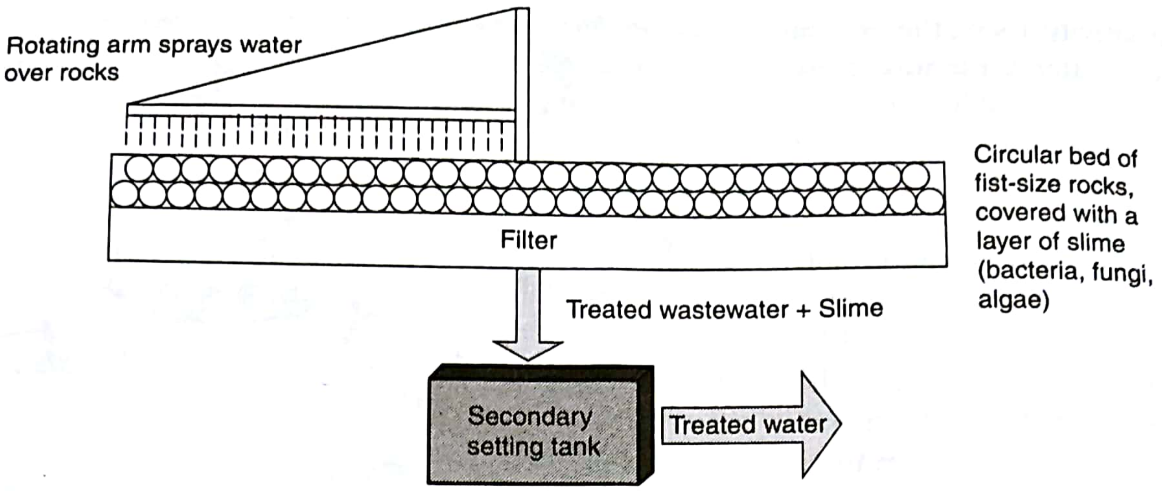
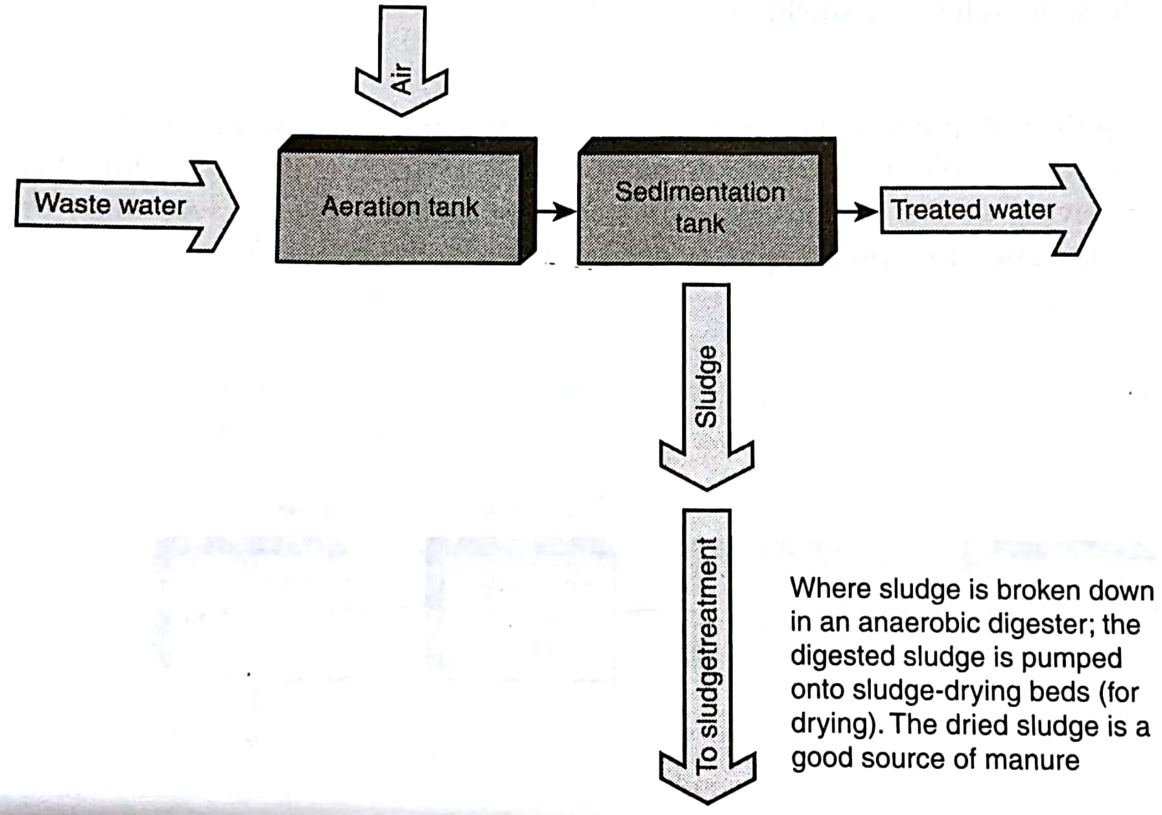

Rotating arm sprays water over rocks
Filter
Circular bed of fist-size rocks, covered with a layer of slime (bacteria, fungi, algae)
Treated wastewater + Slime
Secondary setting tank
Treated water

Fig. 5.8 Secondary treatment—a trickling filter



Where sludge is broken down in an anaerobic digester; the digested sludge is pumped onto sludge-drying beds (for drying). The dried sludge is a good source of manure

Fig. 5.9 Secondary treatment—activated sludge process

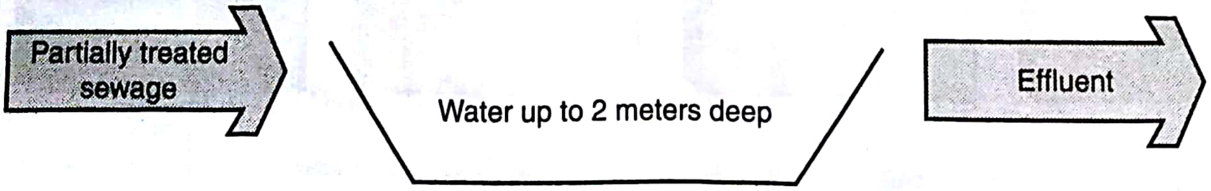


Fig. 5.10 Secondary treatment—oxidation pond

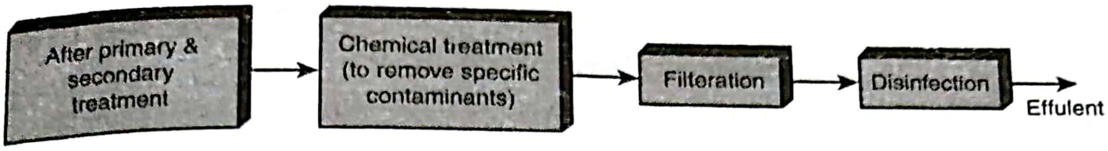

After primary & secondary treatment
Chemical treatment (to remove specific contaminants)
Filteration
Disinfection
Effulent

Fig. 5.11 Advanced sewage treatment

Primary treatment: As shown in Fig. 5.7, primary treatment involves processes such as screening and sedimentation to remove pollutants. This treatment normally removes about 35% of the BOD and 60% of the suspended solids.

Secondary Treatment: The main objective of secondary treatment is to remove most of the BOD. Figures 5.8, 5.9 and 5.10 show three commonly used approaches—trickling filters, activated sludge process and oxidation ponds, respectively. Secondary treatment can remove at least 85% of the BOD.

Pollution Due to Oil

Oil pollution of the sea normally attracts the greatest attention because of its visibility. The main source is tanker operations when ships carry seawater as ballast on their return journey. This ballast water is stored in the cargo compartments that previously contained oil. When the cargo is unloaded, a certain amount of oil remains, clinging to the walls of the container. The ballast water thus becomes contaminated with oil. When a fresh cargo of oil is to be loaded, these compartments are cleaned with water, which discharges the dirty ballast along with the oil into the sea. The other sources include dry docking of ships for repairs, offshore oil production and tanker accidents. The 2010 BP oil spill and the 2010 Mumbai oil spill are recent examples of major disasters impacting our oceans today.

CASE STUDY 4

Oil spill disaster

One of the worst oil spill disasters is that of the *Exxon Valdez*. On 24 March 1989, the *Exxon Valdez*, a tanker more than three football fields wide, went off course in a 16-km-wide channel in Prince William Sound near Valdez in Alaska. It hit submerged rocks, creating an environmental disaster. The rapidly spreading oil slick coated more than 1600 km of shoreline, killing between 300,000 and 645,000 water birds and a large number of sea otters, harbour seals, whales and fish. Exxon spent $2.2 billion directly on the clean up operations. However, some results showed that where high-pressure jets of hot water were used to clean beaches, coastal plants and animals that had survived the spill were killed. Thus, it did more harm than good. Exxon pleaded guilty in 1991 and agreed to pay the Federal Government and the state of Alaska $1 billion in fines and civil damages. This $8.5 billion accident might have been prevented if Exxon had spent only $22.5 million to fit the tanker with a double hull—one inside the other. Such double-hulled vessels would be less likely to rupture and spill their contents. The spill highlighted the need for marine pollution prevention.

CASE STUDY 5

Deepwater Horizon oil spill

The Deepwater Horizon oil spill, also known as the Gulf of Mexico oil spill or the BP oil spill, is considered amongst the largest oil spills in history. On 10 April 2010, an oil well blow-out occurred about 5,000 feet below the ocean surface, causing a catastrophic explosion on the Deepwater Horizon offshore oil drilling platform. Hundreds of millions of litres have been spilt to date. Work to drill relief wells to permanently close the oil well continues. The best estimate of the spill so far is approximately 12,000 to 19,000 barrels of oil per day from the blown-out well. Petroleum toxicity is expected to affect the habitats of thousands of marine species and bird species. Equally, this ongoing environmental disaster has already impacted the Gulf of Mexico fishing industry and tourism industry.

5.5.2 Effects of Marine Pollution

- Phytoplankton blooms or 'red tides' causing a whole area of the water to be discoloured as a result of large amounts of organic waste.
- Clogging of gills of marine species. This further has an impact on commercially important marine species, reducing the market value of seafood.
- Damaging impacts of oil slicks (from liquid oil spilled on the sea) on marine and bird species, salt marshes and mangrove swamps which tend to trap oil, affecting their flowering, fruiting and germination.
- 'Tainting' imparts an unpleasant flavour to fish and seafood and is detectable even at extremely low levels of contamination. Thus, the economic loss from oil slicks on fish and shellfish production facilities can pose a significant threat to the seafood industry.
- Drill cuttings dumped on the seabed create anoxic conditions and result in the production of toxic sulphides in the bottom sediment, thus eliminating the benthic fauna.

How Does Oil Impact Bird Life?

If liquid oil contaminates a bird's plumage, its water-repellent properties are lost. Water then penetrates the plumage and displaces the air trapped between the feathers and skin. This air layer is necessary as it provides buoyancy and thermal insulation. With this, the plumage becomes water-logged and the birds may sink and drown. Even if this does not happen, loss of thermal insulation results in exhaustion of food reserves in an attempt to maintain body temperature, often followed by death. Birds often clean their plumage by preening and in the process consume the oil which, depending on its toxicity, can lead to intestinal, renal or liver failure.

Control Measures for Oil Pollution

Cleaning oil from surface waters and contaminated beaches is a time-consuming and labour-intensive process. The natural process of emulsification of oil in water can be accelerated through the use of chemical dispersants, which can be sprayed on the oil. A variety of slick-lickers in which a continuous belt of absorbent material dips through the oil slick and is passed through rollers to extract the oil have been designed. Rocks and harbour walls can be cleaned with high-pressure steam or dispersants after which the surface must be hosed down.

5.6 NOISE POLLUTION

Noise may not seem as harmful as the contamination of air or water, but it is a problem that affects human health and can contribute to a general deterioration of environmental quality (Fig. 5.12).

Noise is undesirable and unwanted sound. Not all sound is noise. What may be considered as music to one person may be noise to another! It is not a substance that can accumulate in the environment like most other pollutants. Sound is measured in a unit called the decibel (dB).

Several sources of noise pollution contribute to both indoor and outdoor noise pollution. Noise emanating from factories, vehicles and from loudspeakers played during festivals can contribute to outdoor noise pollution, while loudly played radio or music systems and other electronic gadgets can contribute to indoor noise pollution.

Table 5.5 Decibel levels of common sounds

dB	Environmental condition
0	Threshold of hearing
10	Rustle of leaves
20	Broadcasting studio
30	Bedroom at night
40	Library
50	Quiet office
60	Conversational speech (at 1m)
70	Average radio
74	Light traffic noise
90	Subway train
100	Symphony orchestra
110	Rock band
120	Aircraft takeoff
146	Threshold of pain

The differences between sound and noise are often subjective and a matter of personal opinion. There are, however, some very harmful effects caused by exposure to high sound levels. These effects can range in severity from being extremely annoying to being extremely painful and hazardous.

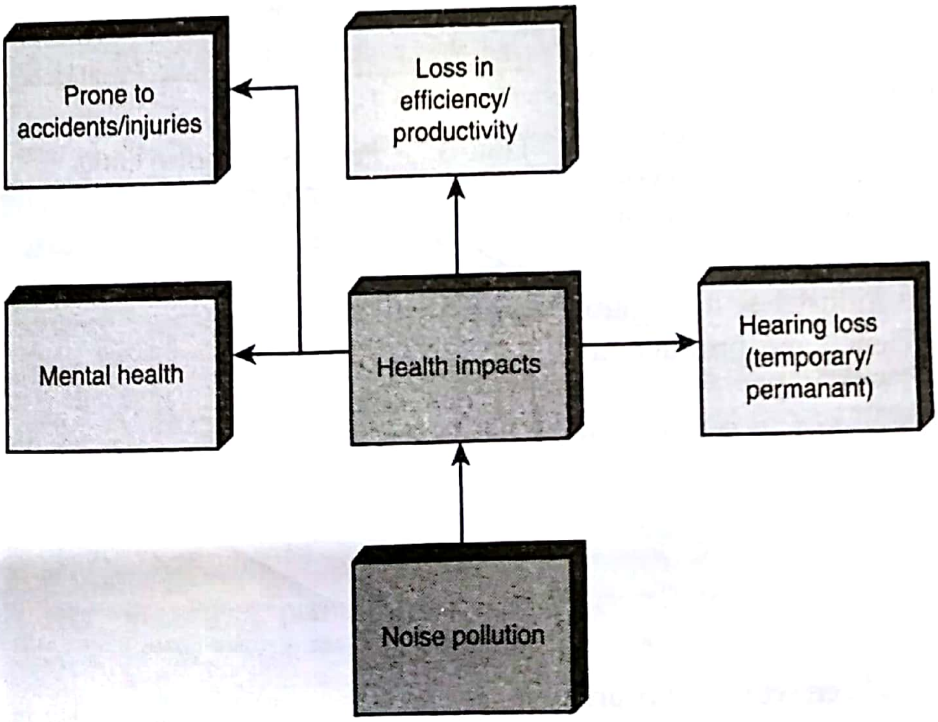

Prone to accidents/injuries
Loss in efficiency/ productivity
Mental health
Health impacts
Hearing loss (temporary/ permanant)
Noise pollution

Fig. 5.12 Impact of noise pollution

5.6.1 Effects of Noise Pollution

Physical Health

The most direct harmful effect of excessive noise is physical damage to the ear, from temporary or permanent hearing loss.

Temporary hearing loss is often called a 'temporary threshold shift' (TTS). People suffering from this condition are unable to detect weak sounds. However, hearing ability is usually recovered within a month of exposure. Permanent loss, usually called 'noise-induced permanent threshold shift' (NIPTS), represents a loss of hearing ability from which there is no recovery. As an example, in Maharashtra, people living in close vicinity of Ganesh *mandals* that play blaring music for the ten days of the Ganesh festival are usually known to suffer from TTS. Below a sound level of 80 dB, hearing loss does not occur at all. However, temporary effects are noticed at sound levels between 80 and 130 dB. About 50% of the people exposed to 95 dB sound levels at work develop NIPTS and most people exposed to more than 105 dB experience permanent hearing loss to some degree. A sound level of 150 dB or more can physically rupture the human eardrum. The degree of hearing loss depends on the duration as well as the intensity of the noise. For example, one hour of exposure to a 100 dB sound level can produce a TTS that may last for about one day. However, in factories with noisy machinery, workers are subjected to high sound levels for several hours a day. Exposure to 95 dB for 8 hours every day for over 10 years may cause about 15 dB of NIPTS. In addition to hearing loss, excessive sound levels can harm the circulatory system by raising blood pressure and altering pulse rates.

Table 5.6 Ambient noise levels (dB)

Zone	Day time	Night time
Silent zone	50	40
Residential zone	55	45
Commercial zone	65	55
Industrial zone	70	70

Table 5.7 Permissible noise limits

Duration	dB
8 hours	90
4 hours	93
2 hours	96
1 hour	99
30 minutes	102
15 minutes	105
7 minutes	108
4 minutes	111
2 minutes	114
1 minute	117
30 seconds	120
Instantaneous rupture of membrane	150

Mental Health

Noise can also cause emotional or psychological effects such as irritability, anxiety and stress. Lack of concentration and mental fatigue are significant health effects of noise.

It has been observed that the performance of school children is poor in comprehension tasks when schools are situated in busy areas of a city and suffer from noise pollution. As noise interferes with normal auditory communication, it may mask auditory warning signals and hence increase the rate of accidents, especially in industries. It can also lead to lower worker efficiency and productivity and higher accident rates on the job.

Thus, noise is more than just a nuisance or annoyance. It definitely affects the quality of life. It is therefore important to ensure mitigation or control of noise pollution.

Permitted Noise Levels

A standard safe time limit has been set for exposure to various noise levels. Beyond this 'safe' time, continuing exposure over a year will lead to hearing loss.

5.6.2 Noise Control Techniques

There are four fundamental ways in which noise can be controlled: (i) reduce noise at the source, (ii) block the path of noise, (iii) increase the path-length and (iv) protect the recipient. In general, the best control method is to reduce noise levels at the source.

Source reduction can be done by effectively muffling vehicles and machinery to reduce noise. In industries, noise reduction can be done by using rigid sealed enclosures around machinery, lined with acoustic absorbing material. Isolating machines and their enclosures from the floor, using special spring mounts or absorbent mounts and pads, and using flexible couplings for interior pipelines also contribute to reducing noise pollution at the source. However, one of the best methods of noise source reduction is the regular and thorough maintenance of operating machinery. Noise levels at construction sites can be controlled using proper construction planning and scheduling techniques. Locating noisy air-compressors and other equipment away from the site boundary, along with creating temporary barriers to physically block the noise, can contribute to reducing noise pollution.

Most of the vehicular noise comes from the movement of the vehicle tyres on the pavement and wind resistance. However, poorly maintained vehicles can add to the noise levels. Traffic volume and speed also have significant effects on the overall sound. For example, doubling the speed increases the sound levels by about 9 dB and doubling the traffic volume (number of vehicles per hour) increases sound levels by about 3 dB. A smooth flow of traffic also causes less noise than does a stop-and-go traffic pattern. Proper highway planning and design are essential for controlling traffic noise. Establishing lower speed limits for highways that pass through residential areas, limiting traffic volume and providing alternative routes for truck traffic are effective noise control measures. The path of traffic noise can also be blocked by constructing vertical barriers along the highway.

To block the path of noise, planting trees around houses can be an effective method. In industries, different types of absorptive material can be used to control interior noise. Highly absorptive interior finish material for walls, ceilings and floors can greatly decrease indoor noise levels. Sound levels also drop significantly with increasing distance from the noise source. *Increasing the path length* between the source and the recipient offers a passive means of control. Municipal land use ordinances pertaining to the location of airports make use of the attenuating effect of distance on sound levels. *To protect individuals* from noise levels, the use of earplugs and earmuffs can be very effective; specially designed earmuffs can reduce the sound level reaching the eardrum by as much as 40 dB. However, workers tend not to wear them on a regular basis despite company requirements for their use.

5.7 THERMAL POLLUTION

Thermal pollution refers to the degradation of water quality as a result of any process that changes the ambient water temperature. It occurs when an industry removes water from a source (such as a river), uses the water for cooling purposes, and then returns the heated water to its source. Power plants, for example, discharge heated water, which is at least 15°C higher than the normal, back into a water body.

5.7.1 Effects

The warmer temperature decreases the solubility of oxygen and increases the metabolism of fish. This changes the ecological balance of the river. Within certain limits, thermal additions can promote the growth of certain fish and the fish catch may be high in the vicinity of a power plant. However, sudden changes in temperature caused by periodic plant shutdowns, both planned and unintentional, can result in the death of these fish that are acclimatised to living in warmer waters.

Tropical marine animals are generally unable to withstand a temperature increase of 2–3°C and most sponges, mollusks and crustaceans are eliminated at temperatures above 37°C. This results in a change in the diversity of fauna, as only those species that can live in warmer water will survive and proliferate excessively. 2

5.7.2 Control Measures

Thermal pollution can be controlled by passing the heated water through: (i) a large shallow cooling pond into which hot water is pumped from one end and cooler water is removed from the other or (ii) a cooling tower after it leaves the condenser. The heat is dissipated into the air and the water can then be discharged into the river or pumped back to the plant to be reused for cooling. The disadvantage in both these methods, however, is that large amounts of water are lost to evaporation.

5.8 NUCLEAR HAZARDS

Nuclear energy can be both beneficial and harmful, depending on the way in which it is used. We routinely use X-rays to examine bones for fractures, treat cancer with radiation and diagnose diseases with the help of radioactive isotopes. Approximately 17% of the electrical energy generated in the world comes from nuclear power plants. However, on the other hand, it is impossible to forget the devastation that nuclear bombs caused in the cities of Hiroshima and Nagasaki. The radioactive waste from nuclear energy has caused, and continues to cause, serious environmental damage.

Nuclear fission is the splitting of the nucleus of the atom; the resulting energy can be used for a variety of purposes. The first controlled fission of an atom was carried out in Germany in 1938. However, the United States was the first country to develop an atomic bomb, which was subsequently dropped on the Japanese cities of Hiroshima and Nagasaki. The world's first electricity generating reactor was constructed in the United States in 1951 and the Soviet Union built its first reactor in 1954. In December 1953, President Dwight D Eisenhower in his 'Atoms for Peace' speech made the following prediction:

'Nuclear reactors will produce electricity so cheaply that it will not be necessary to meter it. The users will pay a fee and use as much electricity as they want. Atoms will provide a safe, clean and dependable source of electricity.'

Although nuclear power is being used today as a reliable source of electricity, the above statement sounds highly optimistic. Several serious accidents have caused worldwide concern about the safety and disposal of radioactive waste.

In order to appreciate the consequences of using nuclear fuel to generate energy, it is important to understand how the fuel is processed. Low-grade uranium ore, which contains 0.2% uranium by weight, is obtained by surface or underground mining. After it is mined, the ore goes through a milling process where it is crushed and treated with a solvent to concentrate the uranium and produces 'yellow cake', a material containing 70%–90% uranium oxide. Naturally occurring uranium contains only 0.7% of fissionable U-235, which is not high enough for most types of reactors. So it is necessary to increase the amount of U-235 by enrichment, although it is a difficult and expensive process. The enrichment process increases the U-235 content from 0.7% to 3%. Fuel fabrication then converts the enriched material into a powder, which is compacted into pellets. These pellets are sealed in metal fuel rods about 4 m in length, which are then loaded into the reactor. As fission occurs, the concentration of U-235 atoms decreases. After about three years, a fuel rod does not have enough radioactive material to sustain a chain reaction and the spent fuel rods must be replaced by new ones. However, these spent rods are still very radioactive, containing about 1% U-235 and 1% plutonium. These rods are a major source of radioactive waste material produced by a nuclear reactor.

Initially, it was thought that spent fuel rods could be reprocessed, not only to provide new fuel but also to reduce the amount of nuclear waste. However, the cost of producing fuel rods by reprocessing was found to be greater than the cost of producing fuel rods from ore. Presently, India does operate reprocessing plants to reprocess spent fuel as an alternative to storing them as nuclear waste. At each step in the cycle, there is a danger of exposure to harmful radiation and this poses several attendant health and environmental concerns.

CASE STUDY 6

Chernobyl disaster

Although nuclear power has significant benefits, an incident which changed people's attitudes towards nuclear power plants was the Chernobyl disaster that occurred in 1986. Chernobyl is a small city in Ukraine, near the border with Belarus, north of Kiev. On 25 April 1986, a test to measure the amount of electricity that the still-spinning turbine would produce if steam were shut off was being conducted at the Chernobyl Nuclear Power Station-4. This was important information, since the emergency core-cooling system required energy for its operation and the coasting turbine could provide some of that energy until another source became available. The amount of steam being produced was reduced by lowering the control rods into the reactor. But the test was delayed because of the demand for electricity and a new shift of workers came on duty. The operators failed to program the computer to maintain power at 700 mW and the output dropped to 30 mW. This presented an immediate need to rapidly increase the power and many of the control rods were withdrawn. Meanwhile, an inert gas (xenon) had accumulated on the fuel rods. This gas absorbed the neutrons and slowed the rate of power increase. In an attempt to obtain more power, the operators withdrew all the control rods. This was a second serious safety violation.

At 1.00 am, the operators shut off most of the emergency warning signals and turned on all the eight pumps to provide adequate cooling for the reactor following the completion of the test. Just as the final stages for the test were beginning, a signal indicated excessive reaction in the reactor. In spite of the warning, the operators blocked the automatic reactor shutdown and began the test. As the test continued, the power output of the reactor rose beyond its normal level and continued to rise.

(Continued)

(Continued)

The operators activated the emergency system designed to put the control rods back into the reactor and stop the fission. But it was already too late. The core had already been deformed and the rods would not fit properly, thus the reaction could not be stopped. In 4.5 seconds the energy level of the reactor increased two thousand times! The fuel rods ruptured, the cooling water turned into steam, and a steam explosion occurred. The lack of cooling water allowed the reactor to explode. The explosion blew the 1000-metric-ton concrete roof from the reactor and the reactor caught fire. This resulted in the world's worst nuclear accident and it took ten days to bring the runaway reaction under control.

There were of course immediate fatalities, but the long-term consequences were devastating—116,000 people were evacuated, of whom 24,000 had received high doses of radiation. Even today, many people suffer from illnesses they feel are related to their exposure to the fallout from Chernobyl. In 1996, ten years after the accident, it was clear that one of the long-term effects was the increased frequency of thyroid cancer in children. There was also a spurt in genetic anomalies as doctors began observing clusters of children born displaying *monoadactyly* (fingers fused together to form a paddle) and *polydactyly* (more than five digits on the hands and feet). A similar phenomenon has also been observed in the villages and towns around the Kalpakkam Nuclear Station, south of Chennai, in an ongoing study by Pugazhendi.

The degree and type of damage from nuclear accidents varies with the kind and amount of radiation, duration of exposure, and the type of cells irradiated. Radiation can also cause mutations, which are changes in the genetic makeup of the cells. Mutations can occur in the ovaries or the testes leading to the formation of mutated eggs or sperms, which in turn can lead to abnormal offspring. Mutations can also occur in the tissues of the body and may manifest themselves as abnormal tissue growths known as cancer. Two common cancers that are linked to increased radiation exposure are leukemia and breast cancer.

5.9 SOLID WASTE MANAGEMENT: CAUSES, EFFECTS AND CONTROL MEASURES OF URBAN AND INDUSTRIAL WASTE

In ancient cities, food scraps and other waste were simply thrown onto the unpaved streets where they accumulated. Around 320 BCE in Athens, the first known law forbidding this practice was established and a system of waste removal began to evolve in several eastern Mediterranean cities. The initial disposal methods were very crude and were often just open pits outside the city walls. As the population increased, efforts were made to transport the waste further away from cities, thus creating city dumps. Until recently, the disposal of municipal solid waste did not attract much public attention. The favoured means of disposal was to dump solid waste outside the city or village limits, and occasionally burn or compact them.

Around most towns and cities in India, the approach roads are littered with multicoloured plastic bags and other garbage. Waste is also burnt to reduce its volume. Modern methods of disposal such as incineration and the development of sanitary landfills are now attempting to solve these problems. The lack of space for dumping solid waste has become a serious problem in several cities and towns all over the world. Dumping and burning waste is not an acceptable practice today, from an environmental or a health perspective. The disposal of solid waste should be part of an integrated waste management plan. The method of collection, processing, resource recovery and final disposal should be synchronised to achieve a common objective.

5.9.1 Characteristics of Municipal Solid Waste

Solid waste is grouped or classified in several different ways. These classifications are necessary to address the complex challenges of solid waste management in an effective manner. The term Municipal Solid Waste (MSW) is generally used to describe most of the non-hazardous solid waste from a city, town or village that requires routine collection and transport to a processing or disposal site. Sources of MSW include private homes, commercial establishments and institutions, as well as industrial facilities. However, MSW does not include waste from industrial processes, construction and demolition debris, sewage sludge, mining waste or agricultural waste.

MSW contains a wide variety of materials. It can contain food waste (like vegetable and meat, leftover food, eggshells), which is classified as wet garbage and paper, plastic, tetrapacks, plastic cans, newspaper, glass bottles, cardboard boxes, aluminum foil, metal items and wood pieces which is classified as dry garbage.

Control Measures

An integrated waste management strategy includes three main components:

- Source reduction
- Recycling
- Disposal

Source reduction is one of the fundamental ways to reduce waste. This can be done by using less material when making a product, reusing products on site and designing products or packaging to reduce their quantity. On an individual level, we can reduce the use of unnecessary items while shopping, buy items with minimal packaging, avoid buying disposable items and also avoid asking for plastic carry bags.

Recycling is reusing some components of the waste that may have some economic value. Recycling has readily visible benefits like conserving resources, reducing energy used during manufacture and reducing pollution levels. Some materials, such as aluminum and steel, can be recycled many times. Mining of new aluminum is expensive and, hence, recycled aluminum has a strong market and plays a significant role in the aluminum industry. Metal, paper, glass and plastics are recyclable. Paper recycling can also help preserve forests, as it takes about 17 trees to make one ton of paper. Crushed glass (*cullet*) reduces the energy required to manufacture new glass by 50%. Cullet lowers the temperature requirement of the glassmaking process, thus conserving energy and reducing air pollution. However, even if recycling is a viable alternative, it presents several problems.

The problems associated with recycling are either technical or economical. Plastics are difficult to recycle because of the different types of polymer resins used in their production. Since each type has a distinct chemical composition, different plastics cannot be recycled together. Thus, separation of different plastics before recycling is necessary. Similarly, in recycled paper, the fibres are weakened and it is difficult to control the colour of the recycled product. Recycled paper is banned for use in food containers to prevent the possibility of contamination. It very often costs less to transport raw-paper pulp than scrap paper. Collection, sorting and transport account for about 90% of the cost of paper recycling. The processes of pulping, de-inking and screening wastepaper are generally more expensive than making paper from virgin wood or cellulose fibres. So, very often recycled paper is more expensive than virgin paper. However, as technology improves, the cost will come down.

Disposal of solid waste is done most commonly through a sanitary landfill or through incineration. A modern sanitary landfill is a depression in an impermeable soil layer that is lined with an impermeable membrane (Fig. 5.13).

Municipal sanitary landfill

The three key characteristics of a municipal sanitary landfill that distinguish it from an open dump are:

- Solid waste is placed in a suitably selected and prepared landfill site in a carefully prescribed manner.
- The waste material is spread out and compacted with appropriate heavy machinery.
- The waste is covered each day with a layer of compacted soil.

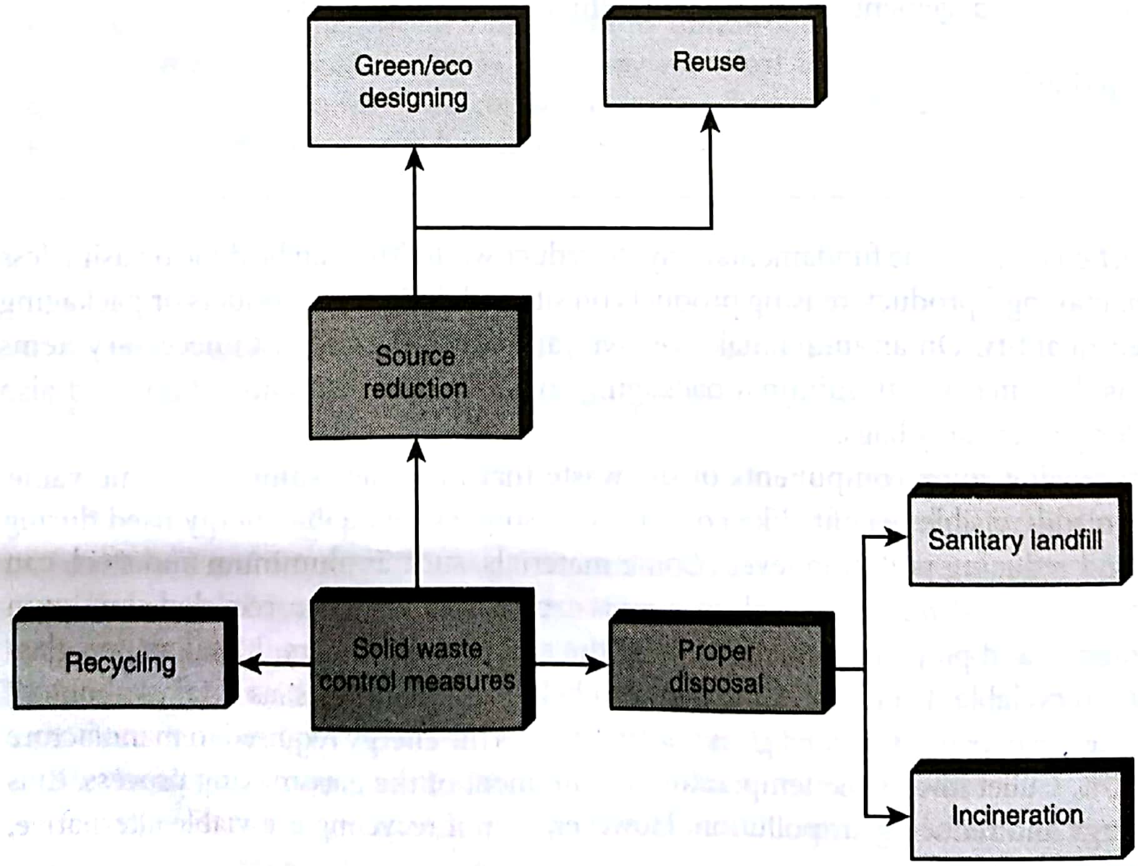


Fig. 5.13 Control measures for solid waste

The problems with older landfills are usually associated with groundwater pollution. Pollutants seeping out from the bottom of a sanitary landfill (leachates) very often percolate down to the groundwater aquifer, no matter how thick the underlying soil layer. Today, it is essential to have suitable bottom-liners and leachate-collection systems along with the installation of monitoring systems to detect groundwater pollution. The organic material in the buried solid waste will decompose due to the action of microorganisms. At first the waste decomposes aerobically until the oxygen that was present in the freshly placed fill is used up by the aerobic microorganisms. Then the anerobes take over, producing methane, which is poisonous and highly explosive when mixed with air in concentrations between 5% and 15%. The movement of the gas can be controlled by providing impermeable barriers in the landfill (Fig. 5.14). A venting system to collect the blocked gas and vent it to the surface, where it can be safely diluted and dispersed into the atmosphere is thus a necessary component of the design of sanitary landfills.

Although landfilling is an economic alternative for solid waste disposal, it has become increasingly difficult to find suitable landfilling sites within economic hauling distance, and very often citizens do not want landfills in their vicinity. Another reason is that no matter how well-engineered the design and operation may be, there is always the danger of some environmental damage in the form of leakage of leachate.

Incineration

It is the process of burning municipal solid waste in a properly designed furnace under suitable temperature and operating conditions. Incineration is a chemical process in which the combustible portion of the waste is combined with oxygen forming carbon dioxide and water, which are released into the atmosphere. This chemical reaction, called oxidation, results in the release of heat. For complete oxidation, the waste must be mixed with appropriate volumes of air at a temperature of about 815°C for about one hour. Incineration can reduce the municipal solid waste by about 90% in volume and 75% in weight. The risks of incineration, however, involve air quality problems and toxicity and disposal of the fly- and bottom-ash produced during the incineration process. Fly-ash consists of finely-divided particulate matter, including cinder, mineral dust and soot. Most of the incinerator ash is bottom-ash while the remainder is fly-ash.

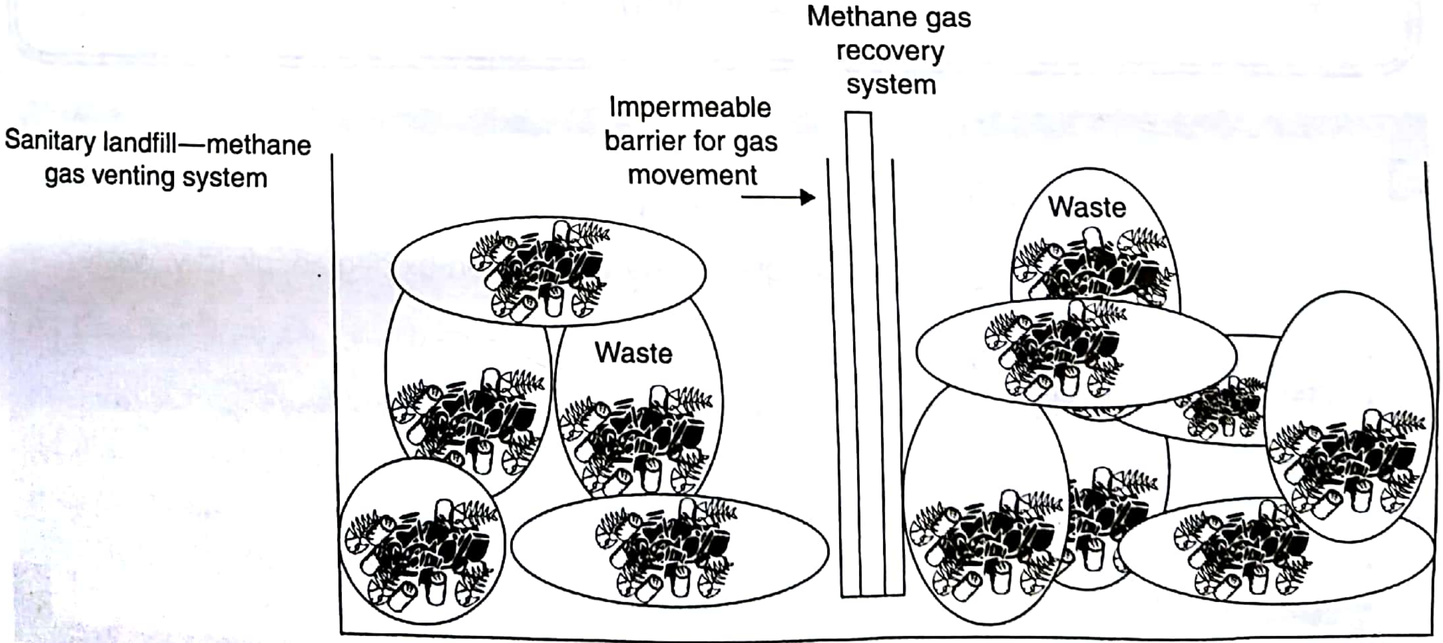

Methane gas recovery system
Impermeable barrier for gas movement
Sanitary landfill—methane gas venting system
Waste
Waste

Fig. 5.14 Modern sanitary landfills

The possible presence of heavy metals in incinerator ash is harmful. Thus, toxic products and materials containing heavy metals (such as batteries and plastics) should be segregated. Extensive air pollution control equipment, high-level technical supervision and skilled employees for proper operation and maintenance are required.

So while sanitary landfills and incinerators have their own advantages and disadvantages, the most effective method of solid waste management is source reduction and recycling.

5.9.2 Vermicomposting

Nature has perfect solutions for managing the waste it creates, if left undisturbed. The biogeochemical cycles are designed to clear the waste material produced by animals and plants. We can mimic the same methods present in nature. All dead and dry leaves and twigs decompose and are broken down by organisms such as worms and insects, and finally by bacteria and fungi, to form a dark rich soil-like material called compost. These organisms in the soil use the organic material as food, which in turn provides them with nutrients for their growth and

Steps for vermicomposting

(i) Dig a pit about half a metre square, one metre deep. You could also use a pot if you stay in a flat. Daily dump and organisation provides beautiful option. Check out their website www.dailydump.org.
(ii) Line it with straw or dried leaves and grass.
(iii) Organise the disposal of organic waste into the pit as and when generated.
(iv) Introduce a culture of microorganisms that is now produced commercially.
(v) Ensure that the contents are covered with a sprinkling of dried leaves and soil every day.
(vi) Water the pit once or twice a week to keep it moist.
(vii) Turn over the contents of the pit every 15 days.
(viii) In about 45 days the waste will be decomposed by the action of the microorganisms.
(ix) The soil derived is fertile and rich in nutrients.

Let's do it!

Can you classify the following into biodegradable (wet) and non-biodegradable (dry) waste?

- Soft drink cans
- Plastic water bottles
- Vegetable scraps
- Fruit peels
- Coconut
- Used milk packets
- Chicken bones

activities. These nutrients are returned to the soil to be used again by trees and other plants. This process recycles nutrients in nature. This soil can be used as manure for farms and gardens.

5.9.3 Hazardous Waste

Modern society produces large quantities of hazardous waste generated by chemical manufacturing companies, petroleum refineries, paper mills, smelters and other industries. Hazardous waste is that which can cause harm to humans or the environment. Waste is normally classified as hazardous when it causes or significantly contributes to an increase in mortality, or an increase in serious irreversible or incapacitating reversible illness, or poses a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of.

Characteristics of Hazardous Waste

Waste is classified as hazardous if it exhibits any of four primary characteristics based on the physical or chemical properties of toxicity, reactivity, ignitability and corrosivity. In addition to this, waste products that are either infectious or radioactive are also classified as hazardous.

Toxic wastes are substances that are poisonous even in very small or trace amounts. Some may have an acute or immediate effect on humans and animals, causing death or violent illness. Others may have a chronic or long-term effect, slowly causing irreparable harm to the exposed persons. Acute toxicity is readily apparent because organisms respond to the toxin shortly after being exposed. Chronic toxicity is much more difficult to determine because the effects may not be seen for years. Certain toxic wastes are known to be carcinogenic (cancer causing) and others may be mutagenic, causing biological changes in the children of exposed people and animals.

Reactive waste is that which has a tendency to react vigorously with air or water, is unstable to shock or heat, generates toxic gases, or explodes during routine management such as gunpowder and nitroglycerine.

Ignitable waste is that which burns at relatively low temperatures (less than 60°C) and is capable of spontaneous combustion during storage, transport or disposal such as gasoline, paint thinners and alcohol.

Corrosive waste is that which destroys materials and living tissue by chemical reaction such as acids and bases.

Infectious waste includes human tissue from surgery, used bandages and hypodermic needles and microbiological materials.

Radioactive waste is the output from nuclear power plants that can persist in the environment for thousands of years before it decays appreciably.

Environmental Problems and Health Risks Caused by Hazardous Waste

As most hazardous waste is disposed of on or in land, the most serious environmental impact is contaminated groundwater. Once groundwater is polluted with hazardous waste, it is very often not possible to reverse the damage.

Lead, mercury and arsenic are hazardous substances, often referred to as heavy metals. Lead is an abundant heavy metal and is relatively easy to obtain. It is used in batteries, fuel, pesticides,

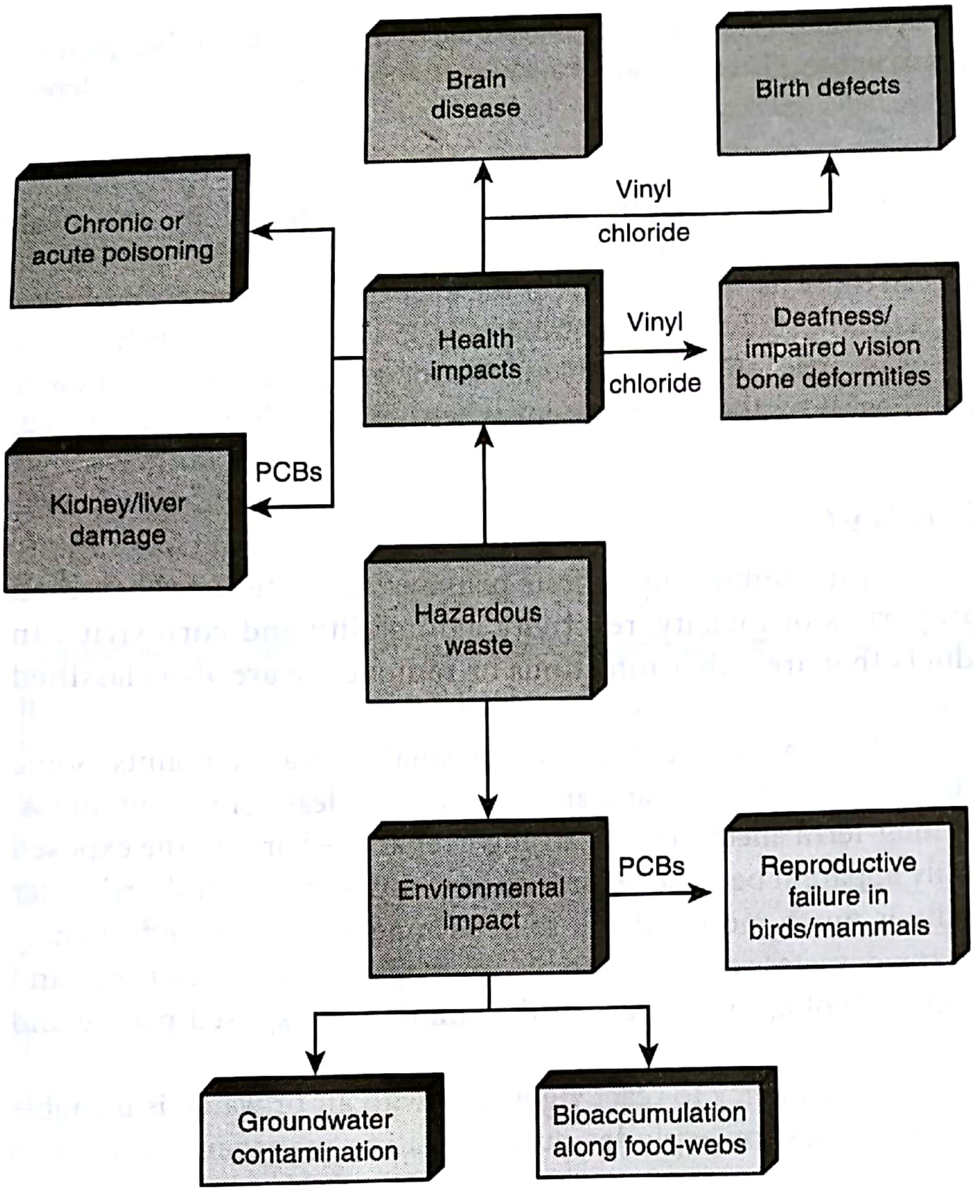

Brain disease
Birth defects
Vinyl chloride
Chronic or acute poisoning
Health impacts
Vinyl chloride
Deafness/ impaired vision bone deformities
PCBs
Kidney/liver damage
Hazardous waste
Environmental impact
PCBs
Reproductive failure in birds/mammals
Groundwater contamination
Bioaccumulation along food-webs

Fig. 5.15 Impact of hazardous waste

paints, pipes and other places where resistance to corrosion is required. Most of the lead absorbed by people and wildlife is stored in the bones. Lead can affect red blood cells by reducing their ability to carry oxygen and shortening their lifespan. Lead may also damage nerve tissue, resulting in brain disease.

Mercury occurs in different forms. It is used in the production of chlorine, and as a catalyst in the production of some plastics. Industrial processes, such as the production of chlorine and plastics, are responsible for most of the environmental damage resulting from mercury. Our body has a limited ability to eliminate mercury. In the food web, mercury becomes more concentrated as it is taken up by various organisms. In an aquatic environment, mercury can be absorbed by plankton, which are then consumed by fish. In addition, fish absorb mercury through their gills and by eating other fish contaminated with mercury. Generally, the older the fish, the greater the concentration of mercury in its body. Birds that eat the fish concentrate even more mercury in their bodies. It is a cumulative poison (it builds up in the body over long periods of time) and is known to cause brain damage.

CASE STUDY 7

Minamata—An important lesson about mercury

A case of human mercury poisoning which occurred about forty years ago in Minamata bay in Japan taught the world an important lesson about the dangers of mercury poisoning. A large plastics plant located near Minamata bay used a mercury containing compound in a reaction to produce vinyl chloride, a common plastic material. The left-over mercury was dumped into the bay along with other waste from the plant. Though the mercury was in its less toxic inorganic state when dumped, the microorganisms at the bottom of the bay converted the mercury into its organic form. This organic mercury then entered into the tissues of fish which were, in turn consumed by the people living in the area. The contaminated fish thus caused an outbreak of poisoning, killing and affecting several people. Mothers who had eaten the contaminated fish gave birth to infants who showed signs of mercury poisoning. Mercury poisoning is thus called 'Minamata disease'.

Thousands of chemicals are used in industries every day. When used incorrectly or inappropriately they can become health hazards. PCBs (polychlorinated biphenyls) are resistant to fire and do not conduct electricity very well, which makes them excellent materials for several industrial purposes. Rainwater can wash PCBs out of disposal areas in dumps and landfills thus contaminating the water. PCBs do not break down very rapidly in the environment and thus retain their toxic characteristics. They cause long-term exposure problems to both humans and wildlife. PCBs are concentrated in the kidneys and liver and cause damage; they cause reproductive failure in birds and mammals.

Vinyl chloride is a chemical that is widely used in the manufacture of plastic. Usually people are only exposed to high levels of vinyl chloride if they work with or near it, but exposure can also occur from vinyl chloride gas leaks. A long continuous exposure (one to three years) in humans can cause deafness, vision problems, circulation disorders and bone deformities. Vinyl chloride can also cause birth defects.

It is essential to substitute the use of PCBs and vinyl chloride with less toxic chemicals. The use of polyvinyl chloride can be lowered by reducing the use of plastics. Thus, by reducing waste, encouraging recycling and using products that are well-made and durable, we can greatly reduce our consumption of these chemicals, thereby curtailing our exposure to these substances.

We may not realise it but many household chemicals can be quite toxic to humans as well as to wildlife. Most of the dangerous substances in our homes are found in various kinds of cleaners, solvents and products used in automotive care.

Today, the most common methods for disposing of hazardous waste are land disposal and incineration. In countries where there is abundant land available for disposal, for example, North America, land disposal is the most widely used method. In countries like Europe and Japan, where land is not readily available and is expensive, incineration is preferred. Despite strong laws, illegal dumping of these wastes continues. Hazardous waste management must move beyond burying and burning. Industries need to be encouraged to generate less hazardous waste in their manufacturing processes. Although toxic waste cannot be entirely eliminated, technology is available for minimising, recycling and treating waste. An informed public can also contribute in a big way towards this end. It is essential for us to understand the ill effects

Let's do it!

What **not** to wash down your drain? Think back to check if you have put any of these items down your drain today.

- Dairy products
- Meat fat
- Cooking oil
- Butter
- Food scraps
- Sauces
- Paint and solvents
- Antibiotics
- Corrosive cleaning products which contain sodium or potassium hydroxide
- Hair

It is important to dispose off all these items in your bins and/or using appropriate mechanical traps to prevent such items from washing down your drain. These items can not only clog your own drainage system (in your house and street) but are also terrible for sewage systems. Sewer pipes tend to overflow if they are blocked by grease, creating a health and environmental hazard to city dwellers.

of chemical substances so that we can make informed decisions about its use. We might decide that the benefits of the use of a toxic substance do not outweigh the risks and choose not to use it at all, or we may decide that it is acceptable to use a substance under specific circumstances where it is adequately controlled and exposure to toxic levels is prevented.

5.10 ROLE OF AN INDIVIDUAL IN THE PREVENTION OF POLLUTION

There are a host of environmental problems caused by human actions on the environment. If we are to respond to these problems, we must recognise that each of us is individually responsible for the quality of the environment we live in. Our personal actions can worsen or improve the quality of our environment. Several people may feel that environmental problems can be solved with quick technological solutions. While most individuals want a cleaner environment, not many of them want to make the changes in their lifestyle that would contribute to a cleaner environment. To a large extent, the decisions and actions of individuals determine the quality of life for everyone. This necessitates that individuals should not only be aware of various environmental issues and the consequences of their actions on the environment, but also make a firm resolve to develop environmentally ethical lifestyles.

With the help of solar energy, natural processes developed over billions of years can indefinitely renew the topsoil, water, air, forests, grasslands and wildlife on which all forms of life depend, but only so long as we do not use these potentially renewable resources faster than they are replenished. Some of our waste can be diluted, decomposed and recycled by natural processes indefinitely as long as these processes are not overloaded. Natural processes also provide services of flood prevention and erosion control at no cost at all. We must therefore learn to value these resources and use them sustainably.

Some concepts that help individuals contribute towards a better quality of environment and human life are:

- Develop respect for all forms of life.
- Each individual must try to answer four basic questions:
  Where do the things that I consume come from?
  What do I know about the place where I live?
  How am I connected to the earth and other living things?
  What is my purpose and responsibility as a human being?
- Plant trees wherever you can and more importantly take care of them. They reduce air pollution.
- Reduce the use of wood and paper products wherever possible. Manufacturing paper leads to pollution and loss of forests which release oxygen and absorb carbon dioxide. Try to recycle paper products and use recycled paper wherever possible.
- From the mail you receive reuse as many envelopes as you can. You can reduce the amount of mail you receive by signing up to receive electronic statements/ bills from banks or phone companies.
- Do not buy furniture, doors or window frames made from tropical hardwoods such as teak and mahogany. These are forest based. Buy furniture made from plantation-based wood such as rubberwood, pine or bamboo.
- Help in restoring a degraded area near your home or join an afforestation programme.
- Use pesticides in your home only when absolutely necessary and use them in small amounts. Some insect species help to keep a check on the populations of pest species.
- Advocate organic farming by asking your grocery store to stock organically grown vegetables and fruits. This will automatically help to reduce the use of pesticides.
- Reduce the use of fossil fuels by either walking short distances or using a car pool, sharing a bike or using public transport. This reduces air pollution.
- Shut off the lights and fans when not needed.
- Do not pour pesticides, paints, solvents, oil or other products containing harmful chemicals down the drain or onto the ground.
- Buy consumer goods in refillable glass containers instead of cans or throwaway bottles.
- Use rechargeable batteries.
- Try to avoid asking for plastic carry bags when you buy groceries or vegetables or any other items. Use your own cloth bag instead.
- Use sponges and washable cloth napkins, dish towels and handkerchiefs instead of paper ones.
- Don't use disposable paper and plastic plates and cups when reusable versions are available.
- Recycle all newspaper, glass, aluminum and other items accepted for recycling in your area. You might have to take a little trouble to locate such dealers.
- Set up a compost bin in your garden or terrace and use it to produce manure for your plants to reduce the use of fertilisers.

- Try to lobby for setting up garbage separation and recycling programmes in your locality.
- Start individual or community composting in your neighbourhood and motivate people to join.
- Do not litter the roads and surroundings just because the sweeper from the municipal corporation will clean it up. Take care to put trash into dustbins or bring it back home with you where it can be appropriately disposed.
- You could join any of the several NGOs that exist in our country or become volunteers. Organise small local community meetings to discuss positive approaches to pollution prevention.
- Learn about the biodiversity of your own area. Understand the natural and cultural assets. This will help you to develop a sense of pride in your city/town/village and will also help you understand the problems facing their survival.
- You cannot improve your world by not voting. You have the option to make a choice rather than complain later.
- Take care to put into practice what you preach. Remember environment protection begins with YOU.

5.11 POLLUTION CASE STUDIES

CASE STUDY 8

Pesticide pollution in India

One of the most terrifying effects of pesticide contamination of groundwater came to light when pesticide residues were found in bottled water. Between July and December 2002, the Pollution Monitoring Laboratory of the New Delhi-based Centre for Science and Environment (CSE) analysed 17 brands of bottled water, both packaged drinking water and packaged natural mineral water, commonly sold in areas that fall within the national capital region of Delhi. Residues of organochlorine and organophosphorus pesticides, which are most commonly used in India, were found in all the samples. Among the organochlorines, gamma-hexachlorocyclohexane (lindane) and DDT were prevalent, while among organophosphorus pesticides, malathion and chlorpyrifos were the most common. All these were present above the permissible limits specified by the European Economic Community (EEC), which is the norm used all over Europe.

One may wonder how these pesticide residues got into bottled water manufactured by several big companies. This can be traced to several facts. There is no regulation that the bottled water industry must be located in 'clean' zones. Currently, the manufacturing plants of most brands are situated in the dirtiest industrial estates or in the midst of agricultural fields. Most companies use bore-wells to pump out water from the ground from depths varying from 24 m to 152 m below the ground. The raw water samples collected from the plants also revealed the presence of pesticide residues. This clearly indicated that the sources of pesticide residues in the polluted groundwater are used

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to manufacture the bottled water. This is despite the fact that all bottled water plants use a range of purification methods. Thus, the fault obviously lies in the treatment methods used.

These plants use membrane technology, where the water is filtered using membranes with ultra-small pores to remove fine suspended solids and all bacteria and protozoa and even viruses. While nanofiltration can remove insecticides and herbicides, it is expensive and thus rarely used. Most industries also use an activated charcoal adsorption process, which is effective in removing organic pesticides but not heavy metals. To remove pesticides, the plants use reverse osmosis and granular activated charcoal methods. So even though the manufacturers claim to use these processes, the presence of pesticide residues points to the fact that either the manufacturers do not use the treatment process effectively or they only treat a part of the raw water.

The low concentrations of pesticide residues in bottled water do not cause acute or immediate effects. However, repeated exposure even to extremely miniscule amounts can result in chronic effects like cancer, liver and kidney damage, disorders of the nervous system, damage to the immune system and birth defects.

Similarly, six months after CSE reported pesticide residues in bottled water, it also found these pesticides in popular cold drink brands sold across the country. This is because the main ingredient in a cold drink or carbonated non-alcoholic beverage is water and there are no standards specified for water to be used in these beverages in India.

There were no standards for bottled water in India till 29 September 2000, when the Union Ministry of Health and Family Welfare issued a notification [no. 759(E)] amending the Prevention of Food Adulteration Rules, 1954. The BIS (Bureau of Indian Standards) certification mark became mandatory for bottled water from 29 March 2001. However, the parameters for pesticide residues remained ambiguous. Following the report published by CSE in *Down to Earth* (Vol 11, no. 18), a series of committees were established and eventually on 18 July 2003, amendments were made in the Prevention of Food Adulteration Rules stating that pesticide residues considered individually should not exceed 0.0001 mg/l and that the total pesticide residues should not be more than 0.0005 mg/l and that the analysis shall be conducted by using internationally established test methods meeting the residue limits specified herein. This notification came into force from 1 January 2004.

CASE STUDY 9

River pollution in India

Almost all the rivers in India are polluted. The causes of pollution may also be more or less similar. This is a case study of the river Damodar as reported in *Down to Earth*. The 563-km-long Damodar river originates near Chandwa village in the Chhotanagpur hills in Bihar's Palamau district. It flows through one of the richest mineral belts in the world before draining into the Hooghly, about 50 km south of Kolkata. Indian industry depends heavily on this region as 60% of the coal consumed in our country

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comes from the Chhotanagpur belt. Coal-based industries of all types dot the area because of locational advantages and the easy availability of water and power. In addition, various industries such as steel, cement, fertiliser and explosive plants are also located here. The river Damodar is polluted with minerals, mine rejects and toxic effluents. Both its water and its sand are infested by coal dust and waste from these industries. There are seven thermal power plants in the Damodar valley. The states of Bihar and West Bengal depend almost entirely on this area for their power requirements. These power plants not only consume a lot of water but also dump ash in the valley.

The river and its tributaries are the largest source of drinking water for the huge population that lives in the valley. On 2 April 1990, about 200,000 litres of furnace oil spilled into the river from the Bokaro Steel Plant. This oil travelled 150 km downstream to Durgapur. For a week after the incident, five million people drank contaminated water in which the oil levels were 40 to 80 times higher than the permissible value of 0.03 mg/l.

The Damodar Action Plan, an end-of-the-pipe pollution treatment scheme, seeks to tackle effluents. One viable option could be to switch to less polluting industries and cleaner technology. This would need strong government initiative and also a mass movement by people.

5.12 DISASTER MANAGEMENT: FLOODS, EARTHQUAKES, CYCLONES, LANDSLIDES

The Indian subcontinent is very vulnerable to droughts, floods, cyclones, earthquakes, landslides, avalanches and forest fires. Among the 36 states and union territories in the country, 22 are prone to disasters.

Among all the disasters, floods are the most frequently occurring natural disasters, due to the irregularities of the Indian monsoon. About 75% of the annual rainfall in India is concentrated in three to four months of the monsoon season. As a result there is very heavy discharge from the rivers during this period, causing widespread floods. Approximately 40 mHa of land in the country has been identified as being prone to floods. The major floods are caused in the Ganga–Brahmaputra–Meghna basin, which carries 60% of the total river flow of our country.

India has a long coastline of 5700 km, which is exposed to tropical cyclones arising in the Bay of Bengal and the Arabian Sea. The Indian Ocean is one of the six major cyclone prone regions of the world. In India, cyclones occur usually between April and May and also between October and December. The eastern coastline is more prone to cyclones as it is hit by about 80% of the total cyclones generated in the region.

Droughts are a perennial feature in some states of India; 16% of the country's total area is drought prone. Drought is a significant environmental problem as it is caused by a lower-than-average rainfall over a long period of time. Most of the drought prone areas identified by the government lie in the arid and semi-arid areas of the country.

Earthquakes are considered one of the most destructive natural hazards. The impact of this phenomenon occurs with so little warning that it is almost impossible to make preparations against damages and collapse of buildings. About 50%–60% of India is vulnerable to seismic activity of varying intensity. Most of the vulnerable areas are located in the Himalayan and sub-Himalayan regions.

The term 'tsunami' comes from the Japanese language, meaning harbour (*tsu*) and wave (*nami*). A tsunami can be generated by any disturbance that rapidly displaces a large mass of water, like an undersea earthquake, volcanic eruption or submarine landslide. The wave travels across the ocean at speeds of 500–1000 km/h. As the wave approaches the land, it 'compresses' – sometimes up to a height of 30 metres – and the sheer weight of the water is enough to crush objects in its path, often reducing buildings to their foundations and scouring exposed ground to the bedrock. The tsunami on 26 December 2004 killed 310,000 people, making it the deadliest tsunami in recorded history.

5.12.1 From Management to Mitigation of Disasters

Until very recently, the approach towards dealing with natural disasters has been post-disaster management, involving problems such as evacuation, warnings, communications, search and rescue, fire-fighting, medical and psychiatric assistance, provision of relief and shelter. After the initial trauma and occurrence of the natural disaster are over and reconstruction and rehabilitation is done by people, NGOs and the Government, its memories are relegated to history.

It is evident today that human activities are responsible for accelerating the frequency and severity of natural disasters. Natural occurrences such as floods, earthquakes and cyclones will always occur. They are a part of the environment that we live in. However, the destruction from natural hazards can be minimised by the presence of a well-functioning warning system combined with preparedness on the part of the community that will be affected. So, although traditionally disaster management consisted primarily of reactive mechanisms, the past few years have witnessed a gradual shift towards a more proactive, mitigation-based approach.

Disaster management is a multidisciplinary area in which a wide range of issues from forecasting, warning, evacuation, search and rescue, relief, reconstruction and rehabilitation are included. It is also multi-sectoral as it involves administrators, scientists, planners, volunteers and communities. These roles and activities span the pre-disaster, during disaster and post-disaster plans. Since their activities are complementary as well as supplementary to each other, there is a critical need for coordinating these activities.

In order to transfer the benefits of scientific research and development to the communities, links must be developed between scientific communities and field agencies. Coordination between government agencies and NGOs needs to be built up so that any overlap of activities may be avoided and ongoing links between the Government and communities are established.

Today, we have a number of early warning systems for a range of natural hazards. Although they are more accurate than before and can help in prediction, it is not enough to ensure that communities are safe from disasters. This is where disaster mitigation can play an important role. 'Mitigation' means lessening the negative impact of the natural hazards. It is defined as sustained action taken to reduce long-term vulnerability of human life and property to natural hazards. While the preparatory, response and the recovery phases of emergency management relate to specific events, mitigation activities have the potential to produce repetitive benefits over time.

Certain guidelines, if followed correctly, can result in an effective mitigation program.

- Pre-disaster mitigation can help in ensuring faster recovery from the impact of disasters.
- Mitigation measures must ensure protection of the natural and cultural assets of the community.

- Hazard reduction methods must take into account the various hazards faced by the affected community and their desires and priorities.
- Any mitigation program must also ensure an effective partnership between the Government, scientific, private sector, NGOs and the community.

The main elements of a mitigation strategy are as follows:

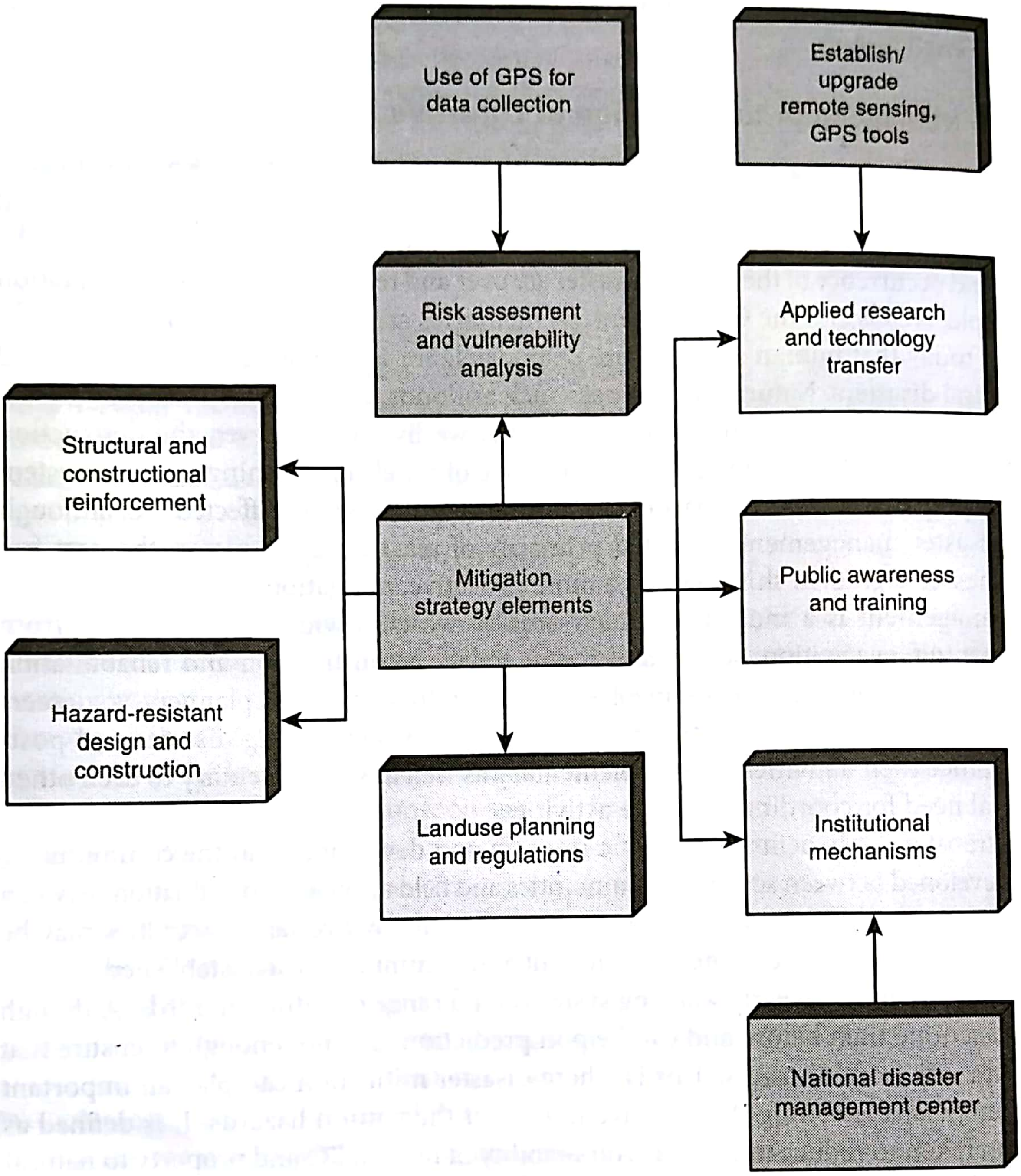

Use of GPS for data collection
Establish/ upgrade remote sensing, GPS tools
Risk assessment and vulnerability analysis
Applied research and technology transfer
Structural and constructional reinforcement
Mitigation strategy elements
Public awareness and training
Hazard-resistant design and construction
Landuse planning and regulations
Institutional mechanisms
National disaster management center

Fig. 5.16 Disaster mitigation strategies

Risk assessment and vulnerability analysis

This involves the identification of hotspot areas of prime concern, collection of information on past natural hazards, information of the natural ecosystems and information on population and infrastructure. Once this information is collected, a risk assessment should be done to determine the frequency, intensity, impact and time taken to return to normalcy after the disaster. The assessment of risk and vulnerabilities will need to be revised periodically. A regular mechanism will therefore have to be established for this. The use of Geographical Information Systems (GIS), a computer program, can be a valuable tool in this process as the primary data can be easily updated and the corresponding assessments can be made.

Applied research and technology transfer

There is a need to establish or upgrade observation equipment and networks, monitor the hazards properly, improve the quality of forecasting and warning, disseminate information quickly through the warning systems and undertake disaster simulation exercises.

Thus, space technologies such as remote sensing, satellite communications and Global Positioning Systems (GPSs) have a very important role to play. Government organisations like ISRO (Indian Space Research Organisation) can play a vital role. Similarly, other government organisations like the National Building Research Organisation, the Meteorological Department or Irrigation Department can undertake applied research for devising locale-specific mitigation strategies in collaboration with educational institutions or universities.

Public awareness and training

One of the most critical components of a mitigation strategy is the training to be imparted to the officials and staff of the various departments involved at the state and district levels. This enables the sharing of information and methodology. The success of a mitigation strategy will depend to a large extent on inter-sectional, inter-departmental coordination and efficient teamwork. Thus, a well-designed training programme taking into account the gaps in knowledge, skills and attitude, with respect to the various tasks that need to be undertaken, is a vital component.

Institutional mechanisms

The most important need at the national level is to strengthen or develop the capacity to undertake disaster mitigation strategies. There is a need to emphasise proactive and pre-disaster measures rather than post-disaster response. It is thus essential to have a permanent administrative structure which can monitor the developmental activities across departments and provide suggestions for necessary mitigation measures. The National Disaster Management Centre (NDMC) can perform such a task. Professionals like architects, structural engineers, doctors and chemical engineers who are involved with management of hazardous chemicals, can be asked to form groups that can design specific mitigation measures.

Incentives and resources for mitigation

To a very large extent, the success of mitigation programmes will depend upon the availability of continued funding. So there is a need to develop mechanisms to provide stable sources of funding for all mitigation programmes. This will include incentives for the relocation of commercial and residential activities outside the disaster-prone areas. Housing finance companies should make it mandatory for structures in such hazard-prone areas to follow special building specifications. The introduction of disaster-linked insurance should be explored and should cover not only life but also household goods, cattle, structures and crops.

Land use planning and regulations

Long-term disaster reduction efforts should aim at promoting appropriate land use in the disaster-prone areas. The separation of industrial areas from residential areas, maintenance of wetlands as buffer zones for floods, creation of public awareness of proper land practices and formation of land use policies for long-term sustainable development are all imperative.

Hazard-resistant design and construction

In areas that are prone to disasters, protection can be enhanced by the careful selection of sites and building technologies. Thus, it is essential to promote the knowledge of disaster-resistant construction materials, techniques and practices among engineers, architects and technical personnel.

Structural and constructional reinforcement of existing buildings

It is also possible to reduce the vulnerability of existing buildings through minor adaptations or alterations, thereby ensuring their safety. This can be done by inserting walls on the outside of the building, buttresses, walls in the interior of the building, portico fill-in-walls, specially anchored frames, covering columns and beams, constructing new frame systems, placing residential electrical equipment above flood level and designing water storage tanks to be able to withstand cyclonic winds, earthquakes and floods.

Floods and Mitigation Measures

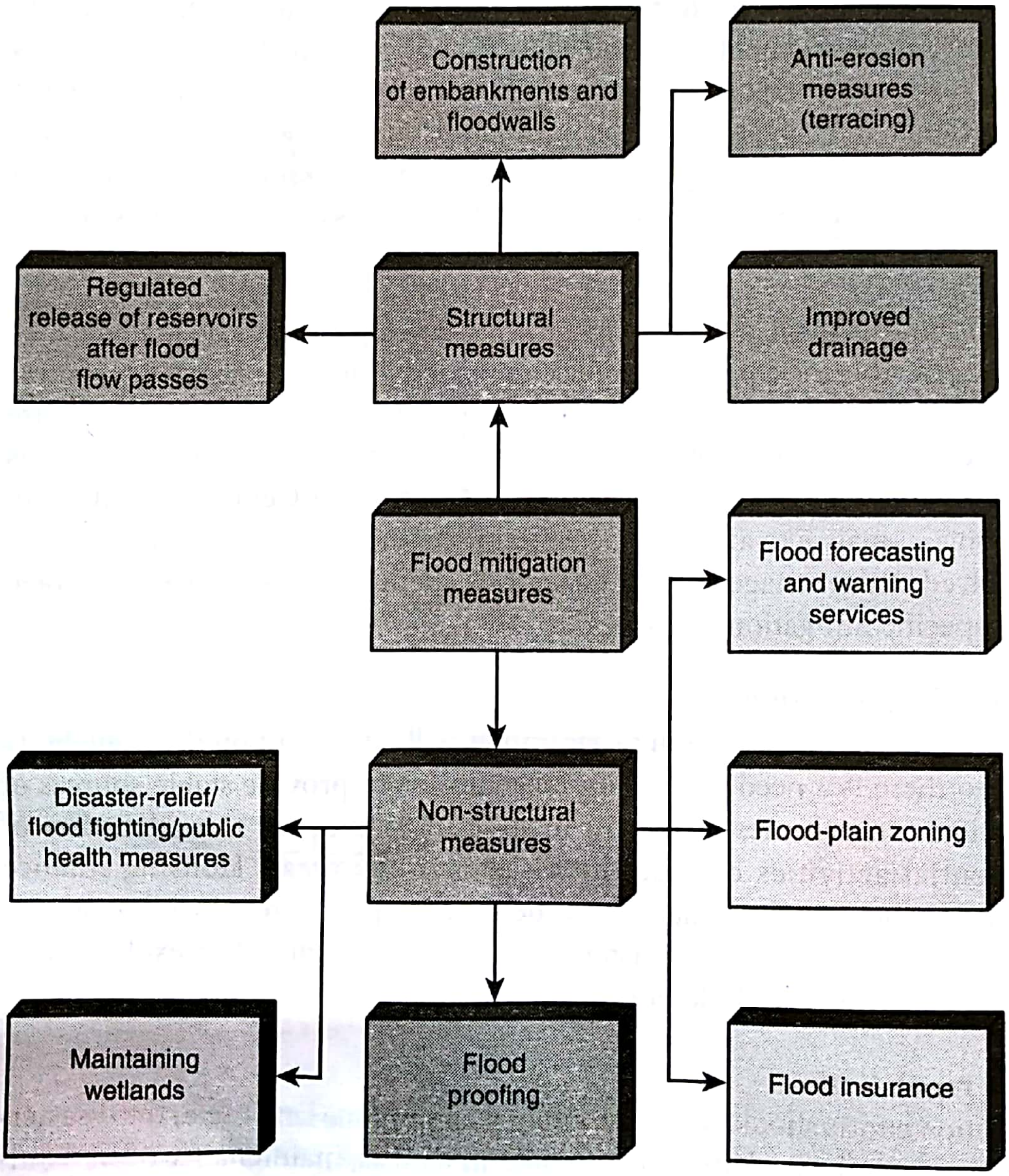

Construction of embankments and floodwalls
Anti-erosion measures (terracing)
Regulated release of reservoirs after flood flow passes
Structural measures
Improved drainage
Flood mitigation measures
Flood forecasting and warning services
Disaster-relief/ flood fighting/public health measures
Non-structural measures
Flood-plain zoning
Maintaining wetlands
Flood proofing
Flood insurance

Fig. 5.17 Flood mitigation measures

The lower plain regions of India, in particular Bihar, Uttar Pradesh and West Bengal with respect to the river Ganga, and Assam with respect to the Brahmaputra, suffer from the adverse effects of floods every year. The Ganga–Brahmaputra basin receives the maximum run-off in the three monsoon months. Based on hydrological studies, it is estimated that only 18% of the rainwater can be stored in dams or reservoirs, while 82% of the rainwater flows through rivers ultimately into the sea. Floods will therefore be a recurring phenomenon in our country.

Floods can be caused by natural, ecological or anthropogenic factors, either individually or as a combined result. Anthropogenic activities, such as deforestation and shifting cultivation, can also contribute to floods. Forests on the hill-slopes normally exert a 'sponge effect', soaking up the abundant rainfall and storing it before releasing it in small amounts over a period of time. However, when the forests are cleared the rivers turn muddy and swollen during the wet monsoon season and run dry later on in the year during the drier periods. An increasing proportion of the rainfall is, therefore, released shortly after precipitation in the form of floods.

The mitigation measures for floods include both structural and non-structural measures. The structural measures include:

- Reservoirs for impounding monsoon flows to be released in a regulated manner after the peak flood flow passes.
- Prevention of over-bank spilling by the construction of embankments and floodwalls.
- Improvement of flow conditions in the channel and anti-erosion measures.
- Improved drainage.

The non-structural measures include:

- Flood-plain management such as Flood Plain Zoning and Flood Proofing, including disaster preparedness.
- Maintaining wetlands.
- Flood forecasting and warning services.
- Disaster relief, flood fighting and public health measures.
- Flood insurance.

Earthquakes and Mitigation Measures

It has been several years since the earthquake struck Gujarat on 26 January 2001. In these years, rehabilitation has been undertaken on a massive scale. Gujarat's experience has taught that building shelters that are less vulnerable to earthquakes should also take into consideration the specific needs of the victims instead of being a top-down approach. The role of NGOs in this is very important. Their strength lies in their resources and informality in operations. Their ability to reach out to the community and sensitivity to local traditions is an asset in such situations. A report on the various initiatives in Gujarat, in *Down to Earth* (Vol 12, No. 2) by Mihir Bhatt, throws light on the various developments that have taken place after the earthquake.

According to the report, the initiatives of the International Fund for Agriculture Development in supporting the Self-Employed Women's Association (SEWA) and the Government's initiative in community-based livelihood security for earthquakes and drought victims have the potential to shape future disaster response and development projects in Gujarat. Similarly, the Gujarat Woman's Economic Development Corporation (GWEDC) initiative in reviving

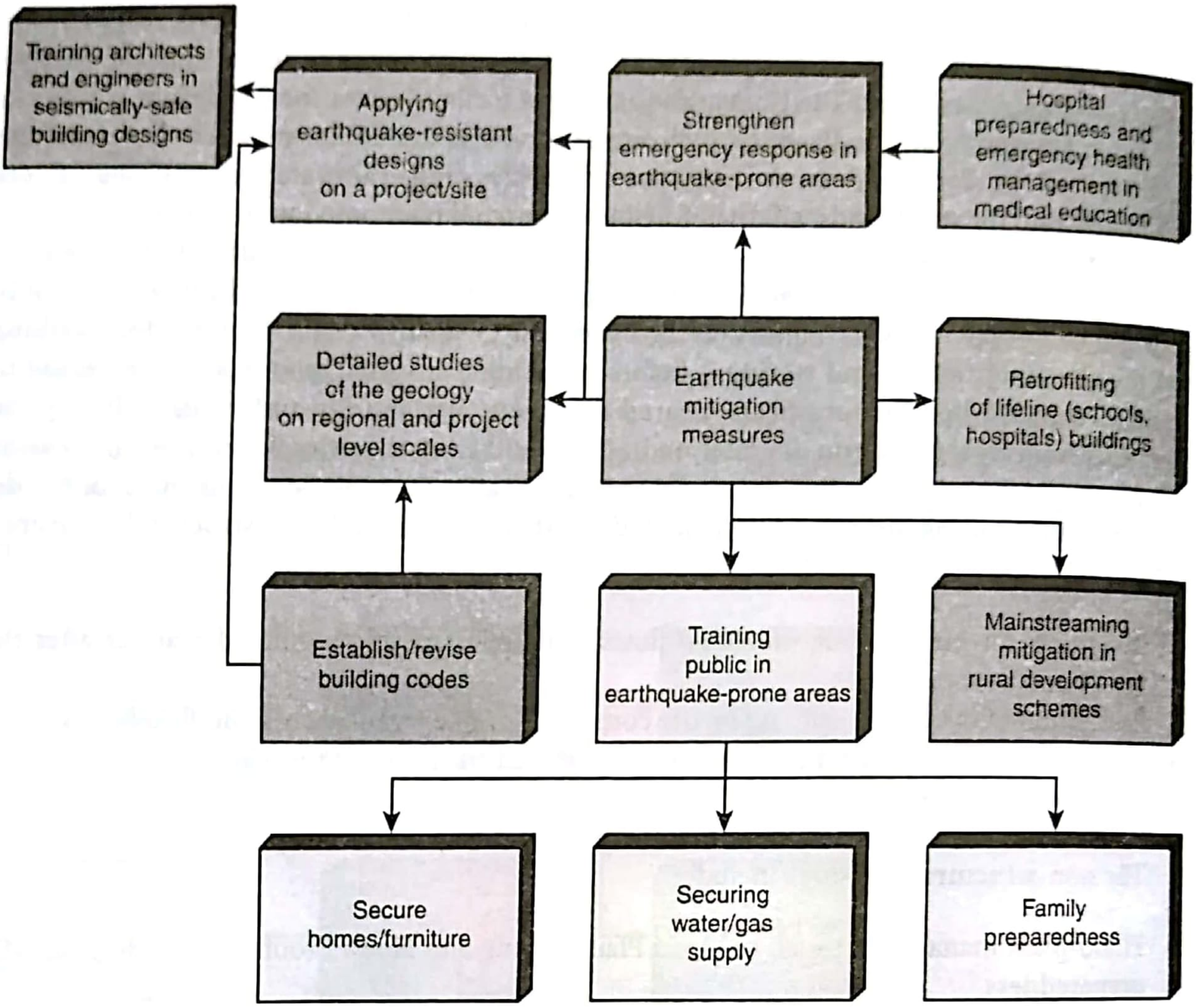

Training architects and engineers in seismically-safe building designs
Applying earthquake-resistant designs on a project/site
Strengthen emergency response in earthquake-prone areas
Hospital preparedness and emergency health management in medical education
Detailed studies of the geology on regional and project level scales
Earthquake mitigation measures
Retrofitting of lifeline (schools, hospitals) buildings
Establish/revise building codes
Training public in earthquake-prone areas
Mainstreaming mitigation in rural development schemes
Secure homes/furniture
Securing water/gas supply
Family preparedness

Fig. 5.18 Earthquake mitigation methods

women's businesses after the calamity also provides many practical lessons in regenerating local economies and artisan markets. This project, supported by the Asian Development Bank, puts a premium on investments in income generation and asset building after a natural disaster. The farming kits provided to affected farmers by Gujarat's agriculture ministry is also showing promising results after two seasons. The author however states that coordination between Government, local NGOs and local community initiatives, both for rescue as well as rehabilitation, needs to be strengthened as this can cause delays, overlaps and waste of relief material and efforts.

Cyclones and Mitigation Measures

Tropical cyclones are the worst natural hazards in the tropics. They are large revolving vortices in the atmosphere extending 150–1000 km horizontally and 12–14 km vertically from the surface. These are intense low pressure areas. Strong winds spiraling anti-clockwise in the Northern Hemisphere blow around the centre of the cyclone at the lower level. At the higher levels, the sense of rotation is the opposite. They generally move 300–5000 km per day over the ocean. While moving over the ocean, they pick up energy from the warm water of the ocean and some

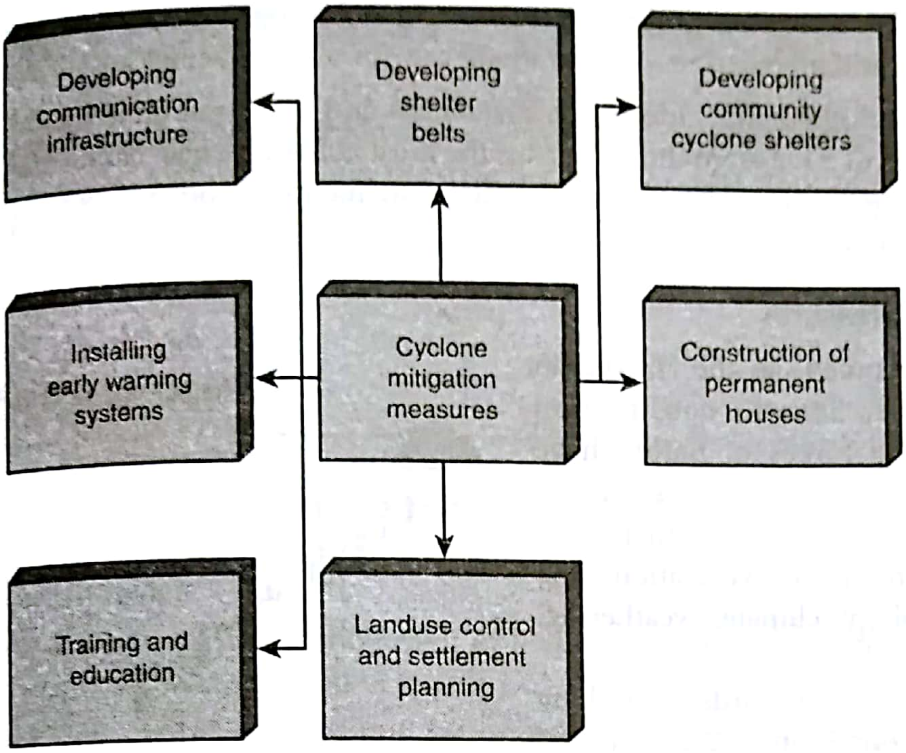

Developing communication infrastructure
Developing shelter belts
Developing community cyclone shelters
Installing early warning systems
Cyclone mitigation measures
Construction of permanent houses
Training and education
Landuse control and settlement planning

Fig. 5.19 Cyclone mitigation methods

of them grow to a devastating intensity. On an average, about 5–6 tropical cyclones form in the Bay of Bengal and the Arabian sea every year, out of which 2–3 may be severe. More cyclones form in the Bay of Bengal than in the Arabian sea. The main dangers from cyclones are very strong winds, torrential rains and high storm tides. Most of the causalities are caused by coastal inundation by storm tides. This is often followed by heavy rainfall and floods. Storm surges cause the greatest destruction.

Although one cannot control cyclones, the effects of cyclones can be mitigated through effective and efficient mitigation policies and strategies. A brief description of the same is given below.

Installation of early warning systems: Such systems fitted along the coastlines can greatly assist forecasting techniques, thus helping in early evacuation of people in the storm surge areas.

Developing communication infrastructure: Communication plays a vital role in cyclone disaster mitigation and yet this is one of the first services that gets disrupted during cyclones. Amateur Radio has today emerged as a second-line, unconventional communication system and is an important tool for disaster mitigation.

Developing shelter belts: Shelter belts with plantations of trees can act as effective wind and tidebreakers. Apart from acting as effective windbreakers and protecting soil crops from being damaged, they also prevent soil erosion.

Developing community cyclone shelters: Cyclone shelters at strategic locations can help minimise loss of human life. In the normal course of life, these shelters can be used as public utility buildings.

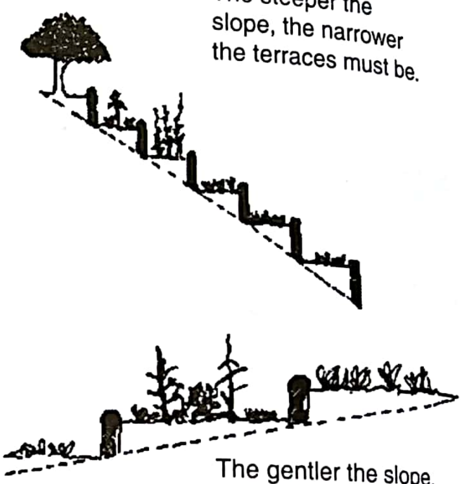
Construction of permanent houses: There is a need to build appropriately designed concrete houses that can withstand high winds and tidal waves.

Training and education: Public awareness programmes that inform the population about their response to cyclone warnings and preparedness can go a long way towards reducing causalities.

Land use control and settlement planning: Ideally, no residential and industrial units should be permitted in the coastal belt of 5 km from the sea, as it is the most vulnerable belt. No further growth of settlements in this region should be permitted. Major settlements and other important establishments should be located beyond 10 km from the sea.

Landslides and Mitigation Measures

Landslides are recurring phenomena in the Himalayan region. In recent years, however, intensive construction activity and the destabilising forces of nature have aggravated the problem. Landslides occur as a result of changes on a slope, sudden or gradual, either in its composition, structure, hydrology or vegetation. The changes can be due to geology, climate, weathering, changing land use and earthquakes.


The steeper the slope, the narrower the terraces must be.
The gentler the slope, the wider the terraces can be.

A significant reduction in the hazards caused by landslides can be achieved by preventing the exposure of population and facilities to landslides and by physically controlling the landslides. Developmental programmes that involve modification of the topography, exploitation of natural resources and change in the balance load on the ground should not be permitted. Some critical measures

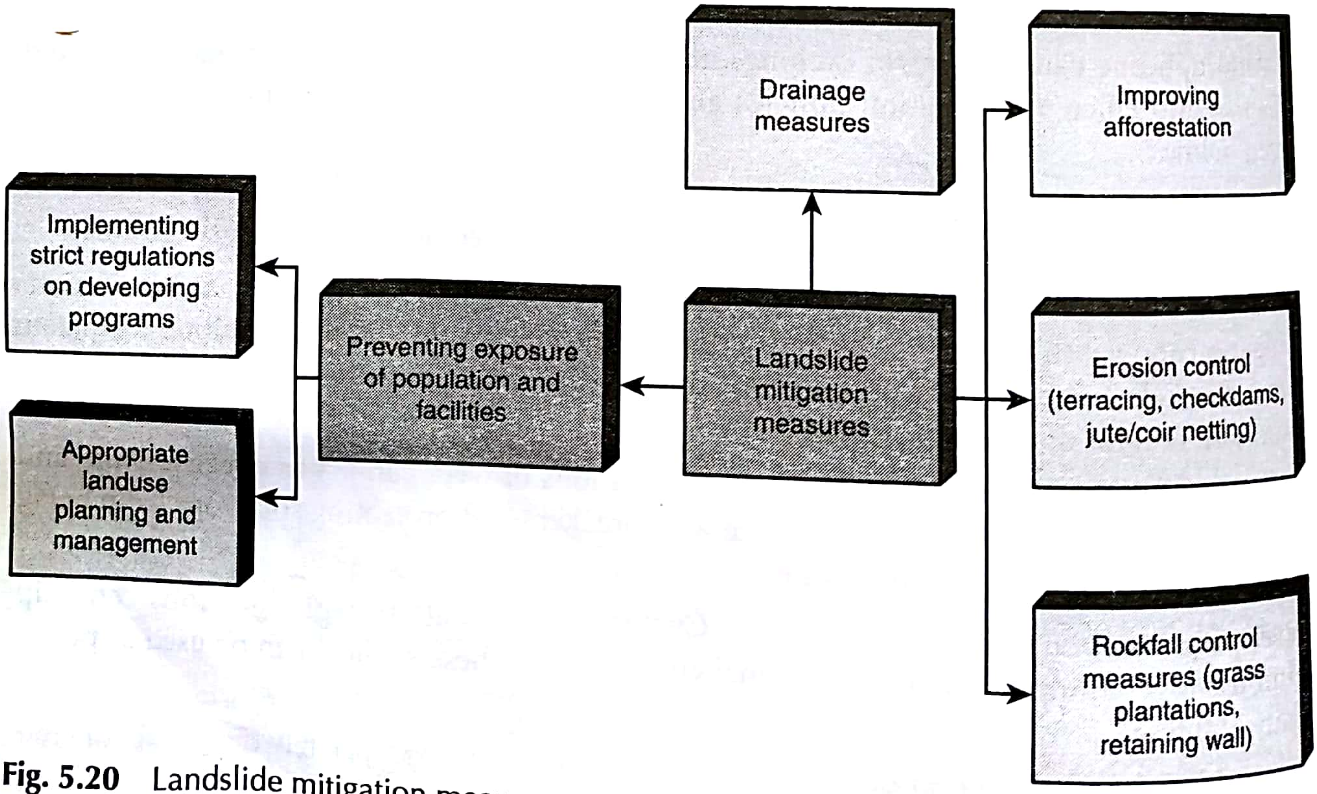

Drainage measures
Improving afforestation
Implementing strict regulations on developing programs
Preventing exposure of population and facilities
Landslide mitigation measures
Erosion control (terracing, checkdams, jute/coir netting)
Appropriate landuse planning and management
Rockfall control measures (grass plantations, retaining wall)

Fig. 5.20 Landslide mitigation measures

that could be undertaken to prevent further landslides are drainage measures, erosion-control measures such bamboo check-dams, terracing, jute and coir netting and rock fall control measures such as grass plantation, vegetated dry masonry walls, retaining walls and, most importantly, preventing deforestation and improving afforestation.

Disasters cannot be totally prevented. However, early warning systems, careful planning and preparedness on part of the vulnerable community would help in minimising the loss of life and property due to these disasters.

Summary

- Air pollution occurs due to the presence of undesirable chemicals, particulate matter or biological materials in the air, in quantities that are harmful to human health and the environment.
- Air pollution affects the health of living organisms, damages plants, harms buildings and materials worth billions of rupees.
- There are devices that remove pollutants before they escape into the air. For example, scrubbers, dry and wet collectors, filters and electrostatic precipitators. Effects of air pollution can also be minimised by building higher smoke stacks that discharge pollutants further away from the ground.
- There are several classes of common water pollutants:
  - disease causing agents such as bacteria and viruses,
  - oxygen-depleting wastes,
  - inorganic plant nutrients such as nitrates and phosphates from fertilisers and pesticides,
  - water-soluble inorganic chemicals such as acids, salts and compounds of toxic metals,
  - organic chemicals such as oil, plastics and cleaning solvents,
  - sediment of suspended matter,
  - water soluble radioactive isotopes, and
  - hot water released by thermal power plants.
- Soil erosion, excessive use of fertilisers and pesticides in farming and soil salinity caused by poor irrigation techniques are some of the major causes of soil pollution.
- Soil erosion is the process of weathering and movement of solids (sediment, soil and other particles) from one place to another. While erosion is a natural process, often caused by wind or flowing water, it has been greatly increased by human activities such as farming, construction, over-grazing by livestock and deforestation.
- The major causes of marine pollution include:
  - discharge of municipal waste and sewage directly into sea,
  - pesticides and fertilisers from agriculture, and
  - petroleum.
- Noise pollution
- Solid waste management
- Disaster management

Questions

1. Discuss the effects of air pollution on living organisms.
2. Write about some of the control measures for air pollution.
3. What is eutrophication?
4. Describe two control measures for oil pollution in water.
5. What is soil erosion?
6. Write about three techniques that can protect soil from erosion.
7. What are some of the common problems arising from landfills?
8. What are some of the steps that you as an individual can take to prevent pollution? Mention at least five.
9. What are the main elements of a disaster mitigation strategy? Mention at least three.
10. Describe two structural mitigation measures and two non-structural mitigation measures that can be taken to manage floods.

Unit 6

Social Issues and the Environment

Let's understand

- How to go from unsustainable to sustainable development
- What the urban problems related to energy are
- What water conservation, rainwater harvesting and watershed management are
- What the problems and concerns involved in resettlement and rehabilitation of people are
- About environmental ethics—the issues involved and possible solutions
- About climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust
- What wasteland reclamation is
- About consumerism and waste products
- About the various Acts—The Environment Act, The Air Act, The Water Act, The Wildlife Protection Act and The Forest Conservation Act
- What the issues involved in enforcement of environmental legislation are
- How to create public awareness

6.1 FROM UNSUSTAINABLE TO SUSTAINABLE DEVELOPMENT

Until two decades ago, the world looked at economic status alone as a measure of human development. Thus, countries that were economically well developed and where people were relatively richer were called advanced nations, while the rest where poverty was widespread and were economically backward were called developing countries. Most countries of North America and Europe, which had become industrialised at an earlier stage, are economically more advanced. They not only exploited their own natural resources rapidly, but also used the natural resources of developing countries to grow even larger economies. So as development progressed, the rich countries got richer while the poor nations got poorer. However, even the developed world has begun to realise that their lives were being seriously affected by the environmental consequences of development based on economic growth alone. This form of development did not add to the quality of life as the environmental conditions had begun to deteriorate.

By the 1970s, most development specialists began to appreciate the fact that economic growth alone could not bring about a better way of life for people unless environmental conditions were improved. Development strategies in which only economic considerations were used, had begun to suffer from serious environmental problems due to air and water pollution, waste management, deforestation and a variety of other ill effects that seriously affected peoples' well being and health. There were also serious equity issues between the 'haves' and the 'have-nots' in society, at the national and global levels. The disparity in the lifestyles between the rich and the poor was made worse by these unsustainable development strategies.

Many decades ago, Mahatma Gandhi envisioned a reformed village community based on sound environmental management. He stressed the need for sanitation based on recycling human and animal manure and well-ventilated cottages built of recyclable material. He envisioned clean roads that were free of dust. His main objective was to use village-made goods instead of industrial products. All these principles are now considered part of sound long-term development. Gandhi had designed a sustainable lifestyle for himself when these concepts were not a part of general thinking. The idea of *sustainable development* grew from various environmental movements, however it was only clearly defined in 1987 by the World Commission on Environment and Development (also know as the Brundtland Commission 1987) as: 'Development that meets the need of the present without compromising the ability of future generations to meet their own needs'. This expresses the idea of environmental, economic and social equity within the limits of the world's natural resources. Sustainable development is based on improving the quality of life for all, especially the poor and deprived, within the carrying capacity of the supporting ecosystems. It is a process which leads to a better quality of life while reducing the impact on the environment. Its strength is that it acknowledges the interdependence of human needs and environmental requirements.

To ensure sustainable development, any activity that is expected to bring about economic growth must also consider its environmental impact (or environmental costs) so that it is more consistent with long-term growth and development. Many development projects – such as dams, mines, roads, industries and tourism development – have severe environmental consequences in terms of their natural resource use, land use and their impact on biodiversity. All these impacts must be studied before any development activity is even begun. Thus, for every project, in a strategy that looks at sustainable development, there must be a scientifically and honestly done EIA, without which the project must not be cleared.

6.2 URBAN PROBLEMS RELATED TO ENERGY

In the past, urban housing in India required relatively smaller amounts of energy than we use at present. Traditional housing in India required very little temperature adjustments as the materials used, such as wood and bricks, handled temperature changes better than the current concrete, glass and steel of ultra-modern buildings.

Embodied energy

Materials like iron, glass, aluminium, steel, cement, marble and burnt bricks, which are used in urban housing, are very energy intensive. The process of extraction, refinement, fabrication and delivery are all energy consuming and add to the pollution of the earth, air and water. The energy consumed in the process is called 'embodied energy'.

Until the 1950s many urban kitchens were based on fuelwood or charcoal. This was possible and practical when homes had chimneys and kitchens were isolated from the rest of the house. Smoke became a problem once this changed to apartment blocks. Kerosene thus became a popular urban fuel. This changed to electrical energy and increasingly to natural gas by the 1970s, in most parts of urban India.

Urban centers in hot climates need energy for cooling. The early systems of fans changed into air-conditioning, which consumes enormous quantities of energy, thus increasing natural resource use. New buildings in our country have taken to using large areas covered by glass. While in cold climates this uses the greenhouse effect to trap the warmth of the sun inside, in our hot climate this adds several degrees to the temperature inside. Thus, it requires even more energy to run large central air-conditioning units. High rise buildings in urban centers also depend on energy to operate lifts and require an enormous number of lights.

Urban transport depends on energy—mainly from fossil fuels. Most urban people use their own individual transport rather than public transport systems for a variety of reasons. Urban transport in different cities and even different parts of a city are either inefficient or overcrowded, so even middle-income groups tend to use their own private vehicles. This means more and more vehicles on the road, which leads to traffic congestion, waste of time for all the commuters, and a great load of particulate matter and carbon monoxide from the exhaust of vehicles. This, in turn, causes a rise in the number of people having serious respiratory diseases. Thus, there is a need to develop a more efficient public transport system and discourage the use of individual vehicles in all our urban areas.

Each of us as environmentally conscious individuals must reduce our use of energy. An unnecessary light left carelessly on adds to energy use. If we learned to save electricity, we would begin to have a more sustainable lifestyle.

CASE STUDY 1

Ahmedabad's bus rapid transit system (BRTS)

While still not completed, Ahmedabad's BRTS has so far provided for a good example of energy efficiency in India's public transport sector. The current 34-km route with a fleet of 45 buses carries approximately 85,000 passengers per day. The bus frequency is approximately 2.5 to 4 minutes during peak hours and 6 to 8 minutes during off-peak hours, ensuring minimal time loss in waiting for buses. Furthermore, Ahmedabad's well planned road network provides for an adaptable BRTS system with minimal land acquisition and traffic planning challenges. More cities in India require such efficient and affordable transport systems.

6.3 WATER CONSERVATION, RAINWATER HARVESTING, WATERSHED MANAGEMENT

6.3.1 Water Conservation

Conserving water has become a prime environmental concern. Clean water is becoming increasingly scarce globally. With deforestation, surface run-off increases and the sub-soil water table drops as water has no time to seep slowly into the ground once the vegetation is cleared.

As many areas depend on wells, it has become necessary to dig deeper and deeper wells. This adds to the cost and further depletes underground stores of water. This could take years to recharge even if the present rate of extraction is reduced, which seems hardly possible in most situations.

When we waste water, we do not realise that it affects all of us in so many different ways. Water has to be equitably and fairly distributed so that household use, agriculture and industry all get a share of the water. The overuse and misuse of water due to various activities and the resulting pollution has led to a serious shortage of potable drinking water. Thus, water conservation is linked closely with overall human well being.

CASE STUDY 2

Pani Panchayat, Pune district, Maharashtra

Mahur village, in the Pune District of Maharashtra, is situated in a drought prone area. The people were not able to grow a good crop in most years; clean drinking water was also scarce. At such a time, Vilasrao Salunkhe initiated a movement known as *Pani Panchayat*, to conserve water in this drought prone area. Watershed development was initiated on a barren and uncultivated piece of land belonging to a temple. Soil conservation and water harvesting, brought about through a comprehensive micro-watershed management program, gradually led to a surplus of water. Out of the 16 ha of land in the village, 9.6 ha were brought under irrigation, 2.4 ha were afforested and 4 ha were converted into percolation tanks. Wells and field bunds were built. While 200 quintals of grains were produced on 24 acres of Salunkhe's land, 40 acres of land in the same area yielded only 10 quintals. This made other villagers follow suit and the area rapidly turned green and productive.

Traditional systems of collecting water and using it optimally have been used in India for many generations. These have been forgotten in the recent past. Conserving water in multiple small percolation tanks and *jheels* was an important feature of traditional forms of agriculture. Villages all over the country had one or more common *talabs* or tanks from which people collected or used water carefully.

As carrying water to their homes over long distances was a time-consuming and laborious activity, the water was not be wasted. Many homes had a kitchen garden that was watered by the waste water. Conservation of water was done in traditional homes through a conscious effort.

During the British period, many dams were built across the country to supply water especially to growing urban areas. After independence, India's policy on water changed towards building large dams for expanding agriculture to support the green revolution. While this reduced the need to import food material and mitigated food shortages in the country, the country began to see the effects of serious water shortages and problems related to its distribution. The newer forms of irrigated agriculture, such as sugarcane and other water-hungry cash crops, required enormous quantities of water. Finally, however, such irrigated areas become waterlogged and unproductive. Thus, the ill effects of the poorly-conceived management of water at the national and local level have made it mandatory to consider a new water policy for the country.

Saving water in agriculture: Drip irrigation supplies water to plants near their roots through a system of tubes, thus saving water. Small percolation tanks and rainwater harvesting can provide water for agriculture and domestic use. Rainwater collected from rooftops can be stored or used to effectively recharge sub-soil aquifers.

Saving water in urban settings: Urban people waste large amounts of water. Leaking taps and pipes are a major source of water loss. Canals and pipes carrying water from dams to the consumer contribute nearly 50% to water loss during transfer. Implementing water distribution infrastructure that reduces such distribution losses as well as reducing the demand for water by saving it, is more appropriate than trying to meet growing demands.

6.3.2 Rainwater Harvesting

As our world faces serious water shortages, every drop of water we can use efficiently becomes great in value. One method is to manage rainwater in such a way that it is used at the source. If as much water as possible is collected and stored, this can be used after the rainy season is over. In many parts of the world, especially in very dry areas, this has been the traditional practice. However, the stored water has to be kept pollution-free and clean so that it can be used as drinking water. Stored water can grow algae and zooplankton (microscopic animals) which can be pathogenic and cause infections. Thus, keeping the water uncontaminated is of great importance.

Current technologies of rainwater harvesting require that all roof and terrace water passes down into a covered tank (below or above ground) where it can be stored for use after the monsoon (Fig. 6.1). This practice is most advantageous in arid areas where clean water is very scarce. However, there are practical difficulties such as constructing large storage tanks which can be expensive.

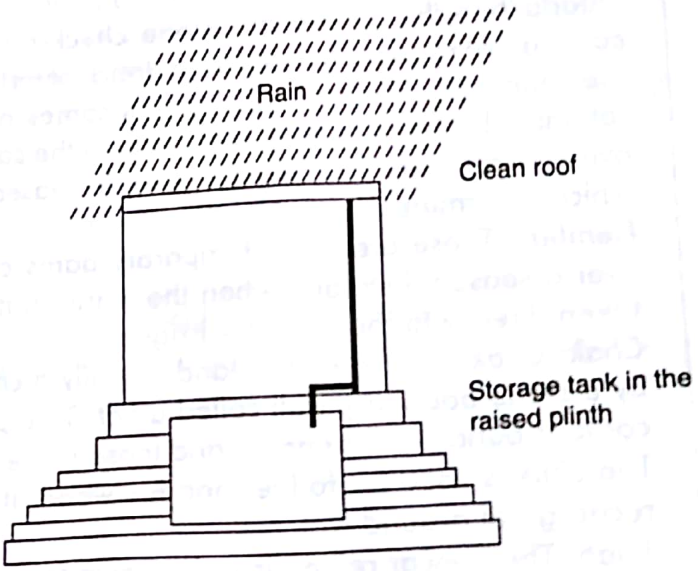


Fig. 6.1 Rainwater harvesting: Storage tank below the ground

Another way of using rooftop rainwater harvesting is to collect the rainwater so that it percolates into the ground to recharge wells instead of flowing over the ground into rivers (Fig. 6.2). Thus, by recharging the groundwater by water harvested from rooftops, the water table rises and the surrounding wells retain water throughout the year.

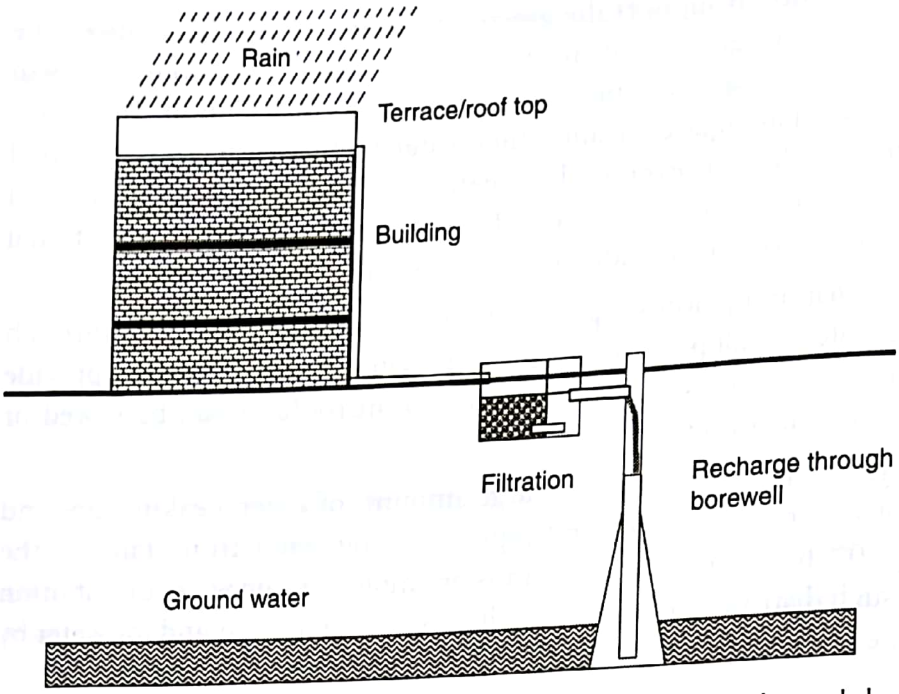


Fig. 6.2 Rainwater harvesting: Recharge of groundwater through borewell

CASE STUDY 3

Mewar, Rajasthan

The Mewar region of Rajasthan has a rich legacy of traditional water harvesting systems to share the available water for cultivation.

Medhbandi: This is a stone embankment built on a hill-slope to help create a level field for cultivation. It controls erosion and conserves moisture.

Naada/bandha: These are stone check-dams across streams or gullies that are constructed to capture runoff on a stretch of fertile land that is submerged in water during the monsoon. The land not only becomes more fertile after trapping silt, but also retains substantial quantities of water in the soil. These dams are constructed in phases over several years. The height is slowly increased up to the same height of the check-dam, which determines the size of the *naada*.

Hembar: These are small temporary dams constructed with stones, twigs and mud over a seasonal stream, when the water in it is reduced to a point that it cannot be taken directly to the fields for irrigation.

Chak: Chak is a big plot of land, usually a *charnot* or village pasture land, enclosed by a stone boundary wall called a *kot*. Tree plantations, seeding of grass for fodder, contour bunds with trenches and loose stone check-dams are developed in the *chak*. The *chak* is used for fodder and fuelwood. It reduces soil erosion and enhances the recharge of ground water.

Talab: The Mewar region is well-known for its built reservoirs (*talabs*). Udaipur city is famous for its large number of *talabs*, and is called the lake city. A small reservoir of less than five *bighas* is called *talai,* a medium-sized lake is called *bandh or talab* and a bigger lake is called *sagar or samand*.

(Continued)

(Continued)

Saza kuva: This is an open dug well, which has several owners. In *Mewari* language, *saza* means partner. This is an important method of irrigation in the Aravalli hills. About 70,000 wells in the Udaipur district provide water for 80% of the area under irrigation and provide water for their owners. These are considered common property resources.

6.3.3 Watershed Management

Rivers originate in streams that flow down mountains and hill-slopes. A group of small streams flow down hillsides to meet larger streams in the valley, which form the tributaries of major rivers. The management of a single unit of land with its water drainage system is called watershed management. This is a technique that has several components including soil and water management, and developing a vegetation cover. The natural drainage pattern of a watershed unit, if managed properly, can bring about local prosperity by providing year-round supply of water, thereby improving the quality of life in the area.

As it provides water throughout the year, health in the community improves as clean water becomes available. Watershed management enhances the growth of agricultural crops and even makes it possible to grow more than one crop in a year in dry areas.

Watershed management begins by taking control of a degraded site through local participation. People must appreciate the need to improve the availability of water both in quantity and quality for their own area. Once they are adequately educated and sensitised, the community begins to understand the project and people begin to work together to promote good watershed management.

Technical steps to take appropriate soil conservation measures for a sound watershed management setup:

Construct a series of long trenches and mounds along the contours of hills to hold the rainwater and allow it to percolate into the ground. This ensures that underground stores of water are fully recharged. This cab be enhanced by growing grasses and shrubs, and planting trees (mainly local species) which hold the soil and prevent it from being washed away in the monsoon.

Note: Local grass cover can only increase if free grazing of domestic animals is regulated or replaced by stall feeding.

Make *nala* plugs in the streams, so that the water is held in the stream and does not rush down the hillside. In selected sites, several small check-dams should be built, which together can hold back larger amounts of water.

6.4 RESETTLEMENT AND REHABILITATION OF PEOPLE: ITS PROBLEMS AND CONCERNS

Any major project such as a dam, mine, expressway or the notification of a National Park, disrupts the lives of the people who live in that area and often requires relocating them to an alternative site. Displacing people is a serious issue. It reduces their ability to subsist on their traditional natural resource base and also creates great psychological pressures. This is especially true of tribal people, whose lives are closely woven around their own natural resources and find it hard to adapt to a new way of life in a new place. Thus, no major project that is likely to displace people can be carried out without the consent of the local people. In India, lakhs of people have been arbitrarily displaced by the thousands of dams built since independence to drive the green revolution. The dams have been built virtually at the cost of these poor local people who have been powerless to resist the Government's will. The Government is expected to find 'good' arable land to resettle these displaced persons and provide them with an adequate rehabilitation package to recover from the disruption. This has rarely occurred to the satisfaction of the individuals affected by the project. In many cases across the country, this has not been implemented satisfactorily for decades.

CASE STUDY 4

Indigenous tribes

It is not just our flora and fauna alone that is under the threat of extinction. Among the many tribes across the globe, the Jarawas of the Andaman islands in the Indian Ocean are dwindling. Dispossession of their customary rights over land has put their survival at risk. They have been compelled to give up their traditional lifestyles, resulting in a rapidly diminishing indigenous population.

Resettlement not only puts pressure on the project-affected people, but also on the people who have been living in the area that has been selected for resettlement. Thus, both the communities suffer and conflict over resources is a distinct possibility in the future.

There are, however, situations where the communities themselves request to be relocated to a new site. This is often observed where people live inside or on the periphery of a national park or wildlife sanctuary. In these situations, such as the Gir in Gujarat, the local people have asked to be given alternate land where they could live peacefully away from lions that kill their cattle, but for decades the Government has been unable to find suitable areas where they can be shifted.

6.5 ENVIRONMENTAL ETHICS: ISSUES AND POSSIBLE SOLUTIONS

Environmental ethics deal with issues related to the rights of individuals that are fundamental to life and well-being. These concern not only the needs of each person today, but also those who will come after us. It also deals with the rights of other living creatures that inhabit the earth.

6.5.1 Resource Consumption Patterns and the Need for Equitable Utilisation

Can individuals justifiably use resources so differently that one individual uses resources many times more lavishly than other individuals who have barely enough to survive? In a just world, there has to be a more equitable sharing of resources than what exists at present. There are rich and poor nations, there are rich and poor communities in every country, and there are rich and poor families. In this era of modern economic development, the disparity between the haves and have-nots is widening. Our human environments in the urban, rural and wilderness sectors use natural resources that shift from the wilderness (forests, grasslands, wetlands) to the rural sector and from there to the urban sector. Wealth also shifts in the same direction. This unequal distribution of wealth and access to land and its resources is a serious environmental concern.

An equitable sharing of resources forms the basis of sustainable development for urban, rural and wilderness-dwelling communities. As the political power base is in the urban centers, this leads to inequalities and a subsequent loss of sustainability in resource management in the rural and forest sectors.

In 1985, Anil Agarwal published the first report on the *Status of India's Environment*. It emphasised that India's environmental problems were caused by the excessive consumption patterns of the rich that left the poor poorer. It was appreciated for the first time that tribals, especially women and other marginalised sectors of our society, were being left out of economic development. There are multiple stakeholders in Indian society who are dependent on different natural resources which cater directly or indirectly to their survival needs. Anil Agarwal brought forth a set of 8 propositions which are of great relevance to the ethical issues that are related to environmental concerns. These include:

(i) Environmental destruction is largely caused by the consumption of the rich.
(ii) The worst sufferers of environmental destruction are the poor.
(iii) Even where nature is being 'recreated', as in afforestation, it is being transformed away from the needs of the poor and towards those of the rich.
(iv) Even among the poor, the worst sufferers are the marginalised cultures and occupations and, most of all, women.
(v) There cannot be proper economic and social development without a holistic understanding of society and nature.
(vi) If we care for the poor, we cannot allow the Gross Nature Product to be destroyed any further. Conserving and recreating nature has become our highest priority.
(vii) The Gross Nature Product will be enhanced only if we can arrest and reverse the growing alienation between the people and the common property resources. Towards this end, we will have to learn a lot from our traditional cultures.
(viii) It is totally inadequate to talk only of sustainable rural development as the World Conservation Strategy does. We cannot save the rural environment or rural people dependent on it, unless we can bring about sustainable urban development.

Equitable use of forest resources: We think of forests as being degraded due to fuelwood collection by poor rural communities, but forget that the rich use much greater quantities of timber. Biomass based industries include cotton textiles, paper, plywood, rubber, soap, sugar, tobacco, jute, chocolate, food processing and packaging. These need land, energy, irrigation and forest resources. Do any of us realise this when we utilise, use excessively or waste these resources that we get indirectly from the forests?

Who pays for the cost of environmental degradation? Most sections of society do not feel the direct effects of degradation of the environment till it is too late. Several marginalised sectors of society are most affected by deforestation, or the loss of grassland tracts, or the deterioration of perennial water sources. All these effects can be linked to increasing unsustainable pressures on land and natural resources. Traditional fishermen who are dependent on streams and rivers, and coastal people who fish and catch crustaceans, are seriously affected by the degradation of our aquatic ecosystems. Fuelwood gatherers from different types of forests, and pastoralists who are dependent on common grazing lands suffer when their resources are depleted.

> 'I am often amazed and extremely angry, when people talk about Environment Education for the villages. It is the so-called, educated people who need environment education more than anyone else.'
>
> —*Anil Agarwal*, 'Human-Nature Interactions in a Third World Country'

Environmental Education—Different Perspectives

- Urban dwellers who are far removed from the source of natural resources that sustain their lives require exposure to a well-designed environment education program to appreciate these issues. While the rural people have a deep insight on the need for sustainable use of natural resources and know about methods of conservation, there are however several newer environmental concerns that are frequently outside their sphere of life experiences. Their traditional knowledge of environmental concerns cannot be expected to bring about an understanding of issues such as global warming, or problems created by pollution and pesticides. These people thus require a different pattern of environment education that is related to their gaps in information. With the rapidly changing rural scenario, the development that is thrust on unsuspecting rural communities needs to be addressed through locale-specific environment awareness programs designed specifically for rural school children and adults. This must also use their local traditional knowledge systems as a base on which modern concepts can be built, rather than by fostering concepts that are completely alien to their own knowledge systems.
- Common property resources in India once included vast stretches of forests, grazing lands and aquatic ecosystems. When the British found that they were unable to get enough wood for ship building and other uses, they converted forest areas into Government 'Reserved Forests' for their own use to grow timber trees. This alienated the local people from having a stake in preserving these resources. This, in turn, led to large scale losses in forest cover and the creation of wasteland. In the past, in traditional villages that were managed by local *panchayats*, there were well-defined rules about managing grazing lands, collecting forest resources and protecting sacred groves that supported conservation. There was a more or less equitable distribution that was controlled by traditional mechanisms to prevent the misuse of common property resources. Any infringement was quickly dealt with by the *panchayat* and the offender was punished. Common property resources were thus locally protected by communities. As landuse patterns changed, these mechanisms were lost and unsustainable practices evolved, frequently as a result of an inadequately planned development strategy.

6.5.2 The Need for Gender Equity

All over India, especially in the rural sector, women work longer hours than men. The life of a woman is enmeshed in an inextricable cycle of poverty. In attempting to eke out a living from their environment, women constantly collect fuelwood for their homes and for sale to nearby urban areas. They laboriously collect fodder for their cattle. They have to trudge several kilometers to reach a reasonably clean water source. And finally, they cook meals in a smoky unhealthy atmosphere on crop or animal waste or other inefficient sources of energy. All this can take 10 to 12 hours a day of very hard work, every day of the year. This begs the question of who should control the environmental resources of a rural community. Unfortunately, it is the men who play a decisive role in managing the village commons and their resources whereas it should really be the local women, whose lives are deeply linked with the utilisation and conservation patterns of natural resources, who should be the decision makers at the local level. Unfortunately, women have not been given an equal opportunity to develop and better their lot. This begins with the lack of attention given to girls whose education is always secondary to that of boys in the family. Unless society begins to see that development cannot be planned by a male-dominated society from the male perspective alone, we will not be able to create a healthier environment for women and their children.

CASE STUDY 5

The Chipko movement

About 300 years ago, a ruler in Rajasthan decided to fell the *khejri* trees in his state to create lime. Local women led by a Bishnoi woman, Amrita Devi, clung to the trees to prevent the felling of the trees that formed the basis of the scarce resources on which they were dependent. The women were ruthlessly massacred. It is said that the ruler later realised his mistake. The story, however, has been remembered and was revived in the 1970s when severe tree-felling for timber in the Himalayas prompted local women, supported by people such as Sunderlal Bahuguna and Chandi Prasad Bhat, to lead a people's movement to prevent deforestation by timber contractors. They called their movement the 'Chipko' movement in memory of the event during which women had clung to their trees and given up their lives. The movement followed the path the 300 Bishnoi women had taken three centuries ago in Rajasthan.

Chipko is a movement primarily begun and supported by the local women in the hills of Uttarakhand and Garhwal, where the women (the traditional fuel collectors) have had to bear the brunt of deforestation. They have not only realised that their fuelwood and fodder resources have receded away from their 'resource use areas' around their settlements due to commercial timber extraction, but that this has led to serious floods and the loss of precious soil.

Chipko activists have made long *padyatras* across the Himalayas protesting against deforestation. The movement has been greatly successful and has been primarily supported by empowering local women's groups, who are the most seriously affected segment. The movement has proved to the world that the forests of the hills are the life-support systems of local communities and are of immense value in terms of local produce, and that the forest provides less quantifiable but even more important ecological services such as soil conservation and the maintenance of the natural water regime of the whole region.

The ability of local women to band together in the foothills of the Himalayas goes back to the pre-independence days when women such as Miraben, a disciple of Gandhiji, moved to this region and understood that it was the deforestation that led to floods and devastation of villages in the valleys and in the Gangetic plains below. They also appreciated that substitution of oak and other broad-leaved forests of the Himalayas with the planting of fast-growing pine for timber and resin was an ecological and social disaster which reduced the forest resources used by traditional hill communities.

6.5.3 Preserving Resources for Future Generations

Can we use up all the resources of the world, leaving nothing for future generations? This ethical issue must be considered when we use resources unsustainably. If we overuse and misuse resources and energy from fossil fuels, what happens to our future generations? A critical concern is to preserve species and natural undisturbed ecosystems that are linked with bioresources, which must be protected for the use of future generations. Just as our ancestors have left resources for us, it is our duty to leave them behind for our future generations. These unborn people have a right to these resources. We only hold the world as trustees for the future generations.

6.5.4 The Rights of Animals

Can humans, a single species, use and severely exploit the earth's resources, which we share with billions of other plant and animal species? The variety of plants and animals that share the earth with us, also have a right to live and share the earth's resources and living space. We have no right to push a species that has taken millions of years to evolve towards extinction. Not only do wild and domesticated animals have a right to life, but have the right to a dignified existence. Cruelty to an animal is no different ethically from cruelty to another human being.

Mahatma Gandhi's philosophy was based on the assumption that human beings were not masters of the other forms of life. He believed that humans were 'trustees of the lower animal kingdom'.

Human beings are just one small cog in the wheel of life on earth. We frequently forget that we have learned to exploit nature and other species well beyond what we should use justifiably. Every plant and animal has a right to life as a part of the earth's community of living things. While nature by itself has natural prey–predator relationships, left to itself, nature maintains a balance in each ecosystem. While evolution has developed a system whereby species become extinct and new ones evolve to fill the world's ecosystems with new plant and animal species, it is human beings alone that have been responsible for the recent rapid decline in the number of species on earth. More importantly, we are now reducing the numbers of so many species that in the near future we will in all probability create a major extinction spasm that will seriously endanger the existence of mankind. Thus, endangering the existence of wild plants and animals and bringing them close to the brink of extinction is not only unfair to those species but also to future generations of people who may find them of great use.

6.5.5 The Ethical Basis of Environment Education and Awareness

Perhaps the most important concern is related to creating an ethos that will support a sustainable lifestyle in society. This brings us to the need for environmental education. The Supreme Court of our country has thus ordered that every young individual at school and college level be exposed to a course on environment. It is not only to create only an awareness of environmental issues, but also to bring about pro-environmental action. Among the variety of tools that can bring home the ethical issues of the environment, no solution is as powerful as real-life experiences.

Creating a love for nature brings about strong pro-environmental action. Our current educational processes at school and college level are being reoriented to bring this about.

There are two aspects that are closely connected with ethical issues that are related to our environment. These are based on valuing nature and appreciating the beauty of nature and treasuring the magnificence of the wilderness.

CASE STUDY 6

Education in nature—the Shantiniketan model

Rabindranath Tagore founded *Shantiniketan*, a university that taught an environment-based philosophy. Tagore's philosophy of education focused upon the need for a harmonious association between human beings and their environment. To achieve this, he relied on exposing young people to nature. This went back to our roots where learning centres were established in remote forests in ancient India. Tagore linked these concepts with celebrations of nature through music, dance, drama and poetry. At Shantiniketan, there were celebrations for each season and ceremonial tree planting. He started *Vriksharopan* way back in 1928. In fact much of what was initiated in Shantiniketan is now accepted as the route to environment education and sustainable living and is essentially based on preserving nature.

In today's world where many of us are far removed from nature, we need to remind ourselves that everything we use, if tracked back to its source, has come from nature. We depend on an intact unpolluted world which is based on nature's goods and services. No life is possible without this. Nature's resources, that we all use and depend on, can only be optimised if they are equitably shared by all of us. If the disparity is too great it can only result in anarchy.

Bringing back an ethic for nature conservation requires environment education and conservation awareness. The best way to do so is to expose young people not only to our dependence on natural resources from the wilderness, but by bringing about an appreciation of the beauty and wondrous aspects of nature. This forms a sharp contrast to the sad plight of degraded areas and polluted sites in which most of humanity now lives in the developed and developing world.

Appreciating the Beauty of Nature and Treasuring the Magnificence of the Wilderness

We often take nature for granted. We rarely take the opportunity to gaze at a scenic sunset, spend time to sit in the incredible silence of the forest, listen to the songs of birds and the sound of the wind rustling through the leaves, take the trouble to watch the magic of a seed germinating from the ground and gradually growing into a seedling over several days, observe a tree through a round of seasons as it gets new leaves, flowers, fruit and seeds, or reflect on the incredibly large number of links between all the different animals and birds that depend on the seasonal changes in their habitat. It is the beauty of nature that gives it an intrinsic value which we tend to ignore. These are not mundane day-to-day events, they are magical aspects of nature's clock that is ticking silently all around us. If we experience these wondrous aspects of nature, our lives will be immeasurably enriched.

Once we realise that the wilderness has a value all its own, this puts man in his rightful role as a custodian of nature rather than an exploiter. Visit a wilderness area, a forest, lakeside, waterfall or seashore where man's hand has not made drastic changes to the ecosystem and one begin to value its beauty. Without the wilderness, the earth would be a sad, bleak, human-dominated landscape. The problem is how much of the wilderness can we preserve in the presence of an ever-growing hunger for land and resources for its utilitarian value. Unless we begin to see the ecological value of the wilderness, an ethic for its conservation cannot become part of our daily lives. And without wilderness, the earth will eventually become unlivable.

Ahimsa or non-violence towards life, which includes all plants and animals, provides India with its basic philosophy which early Hindu philosophers and later sages such as Buddha, Mahavir and Mahatma Gandhi spoke of. Buddhist and Jain philosophy is intrinsically woven around non-violence and the great value of all forms of life. It brings in the notion that animals are not to be viewed purely for their utility value but are a part of the earth's oneness which is linked with our own lives. In Indian philosophy, the earth itself is respected and venerated. In contrast, in Western thought, nature is to be subjugated and used. These are basic differences in thinking processes. Several modern philosophers in the West have now begun to see these Eastern patterns of thought as a new basis for human development. This shift from a purely utilitarian or scientific exploitation of nature to one of harmony with nature, can however only occur, if each of us understands and respects nature's great 'oneness'.

6.5.6 The Conservation Ethics and Traditional Value Systems of India

In ancient Indian tradition, people have always valued mountains, rivers, forests, trees and animals. Thus, much of nature was venerated and protected. Forests have been associated with the names of forest gods and goddesses, both in the Hindu religion as well as in tribal cultures. 'Tree' goddesses have been associated with specific plant species. *Ficus religiosa*, the peepal tree, is venerated and is not to be cut down. The Banyan tree in some regions, such as Maharashtra, is venerated once a year by tying a thread around it as a symbol of respect. The *Tulsi* plant is grown in every home.

Patches of forests, now called 'sacred groves', have been dedicated to the local deity in many Indian cultures, especially in tribal areas. These traditionally protected forest patches depict the true nature of undisturbed vegetation and have a large number of indigenous plant species; their exploitation has been controlled through local sentiments.

Certain species of trees have been protected as they are valued for their fruit or flowers. The mango tree is protected for its fruit around most farms even when wood becomes scarce. The Mahua tree (*Madhuca indica*) is protected by tribal people as it provides edible flowers, oil from its seeds and is used to make a potent alcohol. Many plants, shrubs and herbs are used in Indian medicines, which were once available in the wild in plenty. These are now rapidly vanishing. Many species of animals are venerated as being the *vahan* or vehicle of various gods who are said to travel through the cosmos on them!

In Indian mythology, the elephant is associated with Ganesha. The elephant-headed Ganesha is also linked to the rat. Vishnu is associated with the eagle. Rama is linked to monkeys. In mythology, Hanuman, the monkey god, rendered invaluable help to Rama during his travels to Lanka. The sun god, Surya, rides a chariot drawn by several horses on which he moves through the sky. The lion is linked to Durga and the blackbuck to the moon goddess. The cow is associated with Krishna, the snake with Shiva and Vishnu, the swan with Saraswathi. Vishnu's incarnations have been represented as taking various animal forms which serially include a fish, a tortoise, a boar, a dwarf and a half-man half-lion form.

The associations with various plants that have been given a religious significance include Tulsi, which is linked to Lakshmi and Krishna. The Tulsi plant is also linked to the worship of one's own ancestors. The peepal tree is said to be the tree under which Buddha attained enlightenment. It is also associated with Vishnu and Krishna. Several trees are associated with the goddess Lakshmi, including Amalaki, Mango and the Tulsi shrub.

Traditions also held that these species, which were considered as an important aspect of nature, were the basis of local life-support systems and were integral to bring about a harmonious life. In traditional societies of the past, these examples were all a part of the ethical values that protected nature. As modern science based on the exploitation on nature spread into India, many of these traditions began to lose their effectiveness as measures that helped in conserving nature.

Concepts that support nature's integrity must thus become a part of our modern educational systems. This constitutes a key solution to bring about a new ethic of conserving nature and living sustainable lifestyles.

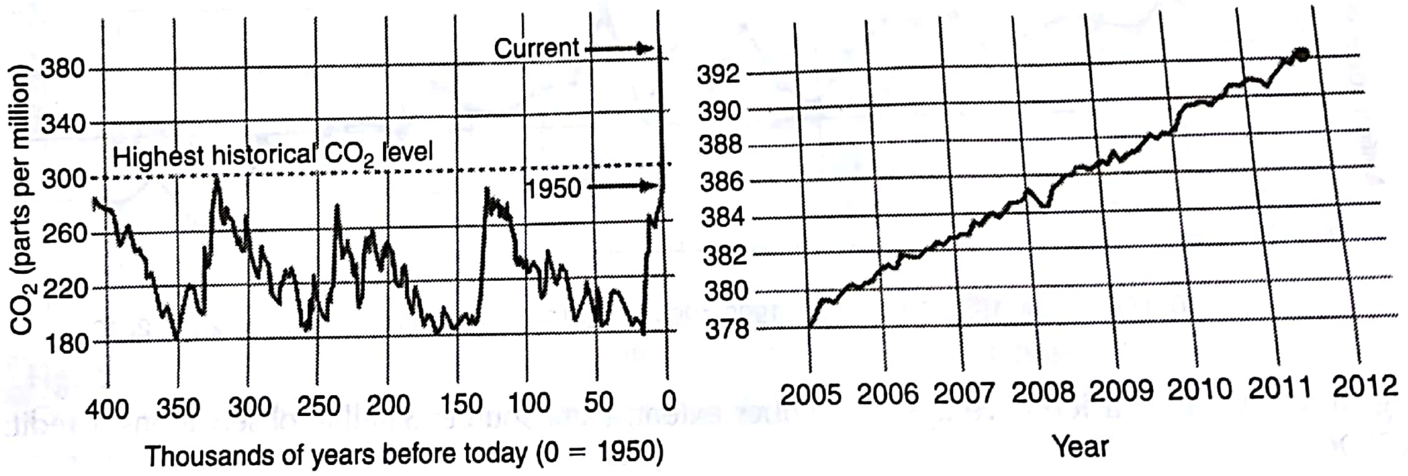
6.6 CLIMATE CHANGE, GLOBAL WARMING, ACID RAIN, OZONE LAYER DEPLETION, NUCLEAR ACCIDENTS AND HOLOCAUST

6.6.1 Climate Change

Today climate change is an accepted fact unlike a decade ago, where scientists and governments were arguing about its existence. There are today five key signs of climate change as suggested by data from the NOAA, US.

Increase in global concentration of carbon dioxide

Carbon dioxide (CO_2) is an important heat-trapping (greenhouse) gas, which is released through human activities such as deforestation and burning fossil fuels, as well as natural processes such as respiration and volcanic eruptions. Figure 6.3(a) shows the CO_2 levels in the earth's atmosphere during the last three glacial cycles, as reconstructed from ice cores and Fig 6.3(b) shows CO_2 levels in recent years, corrected for average seasonal cycles.



(a) (b)

Fig. 6.3 Carbon dioxide concentration: (a) Levels of CO_2 in the past by proxy (indire measurements (Data source: Reconstruction from ice cores. Credit: NOAA) (b) Levels of C in recent times by direct measurements: 2005–present [Data source: Monthly measureme (corrected for average seasonal cycle); Credit: NOAA]

Increase in global surface temperature

Figure 6.4 illustrates the change in global surface temperature relative to 1951–1980 average temperatures. Global surface temperatures in 2010 tied 2005 as the warmest on record (Source: NASA/GISS). The gray error bars represent the uncertainty in measurements. This research is broadly consistent with similar constructions prepared by the Climatic Research Unit and the National Atmospheric and Oceanic Administration.

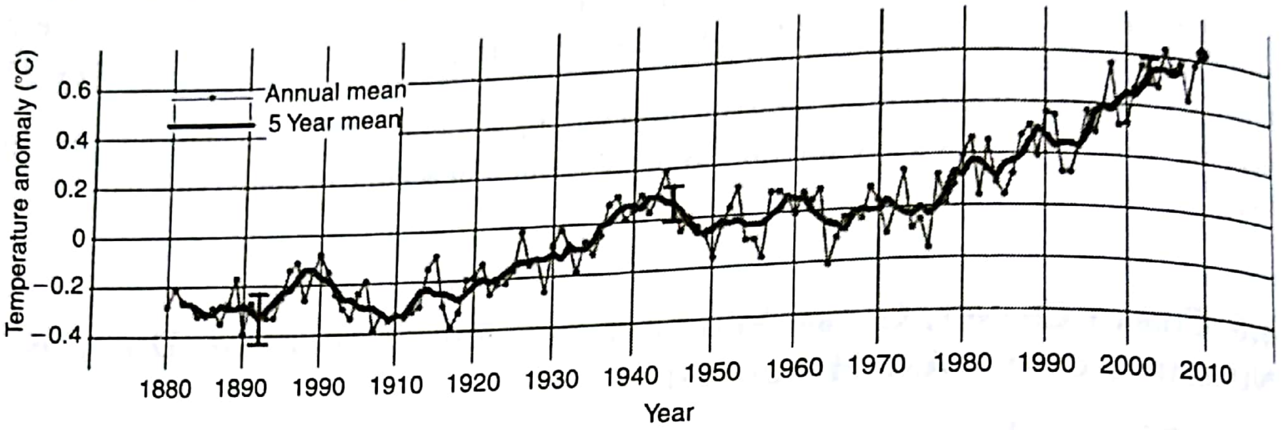


Fig. 6.4 Global surface temperature [Global land-ocean temperature index; Data source: NASA's goddard institute for space studies (GISS) this trend agrees with other global temperature records provided by the U.S. national climatic data center, the japanese meteorological agency and the met office hadley center/climatic research unit in the U.K; Credit: NASA/GISS]

Decline of the arctic sea ice

The Arctic sea ice (September) is now declining at a rate of 11.5% per decade, relative to the 1979 to 2000 average. Arctic sea ice reaches its minimum each September. Figure 6.5 shows the extent of average monthly Arctic sea ice in September from 1979 to 2010, derived from satellite observations. The September 2010 extent was the third lowest in the satellite record.

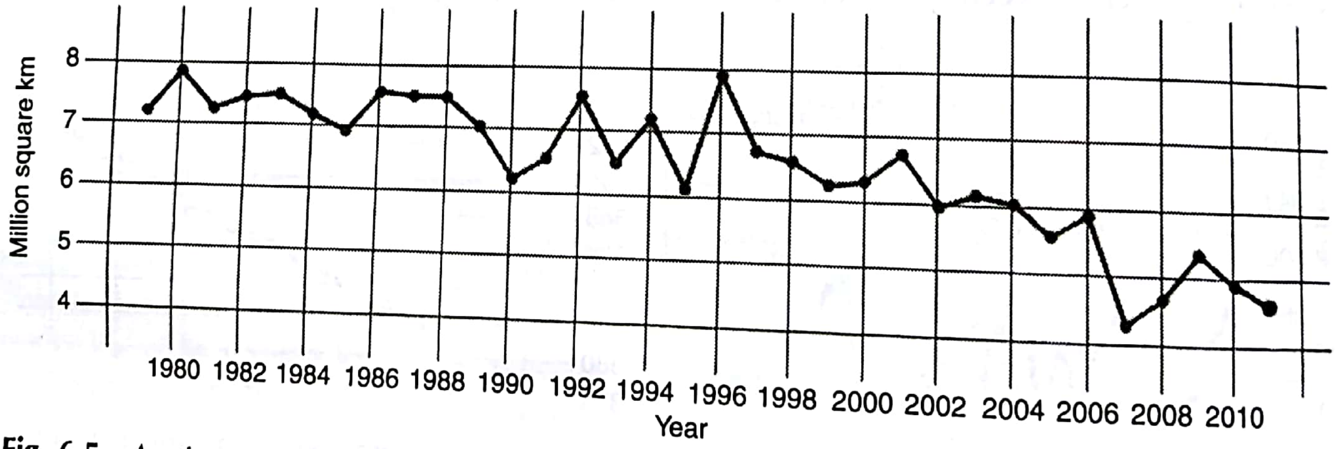
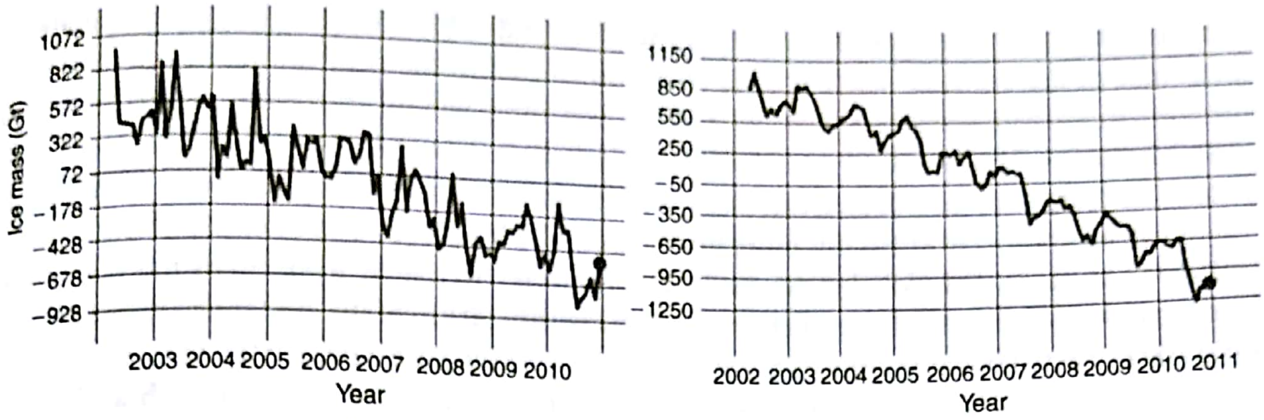


Fig. 6.5 Arctic sea ice (Average september extent; Data source: Satellite observations; Credit: NSIDC)

Decrease in land ice

Data from NASA's Grace satellites show that the land ice sheets in both Antarctica [Fig. 6.6(a)] and Greenland [(Fig. 6.6(b)] are losing mass. The continent of Antarctica has been losing more than 100 cubic kilometers (24 cubic miles) of ice per year since 2002.



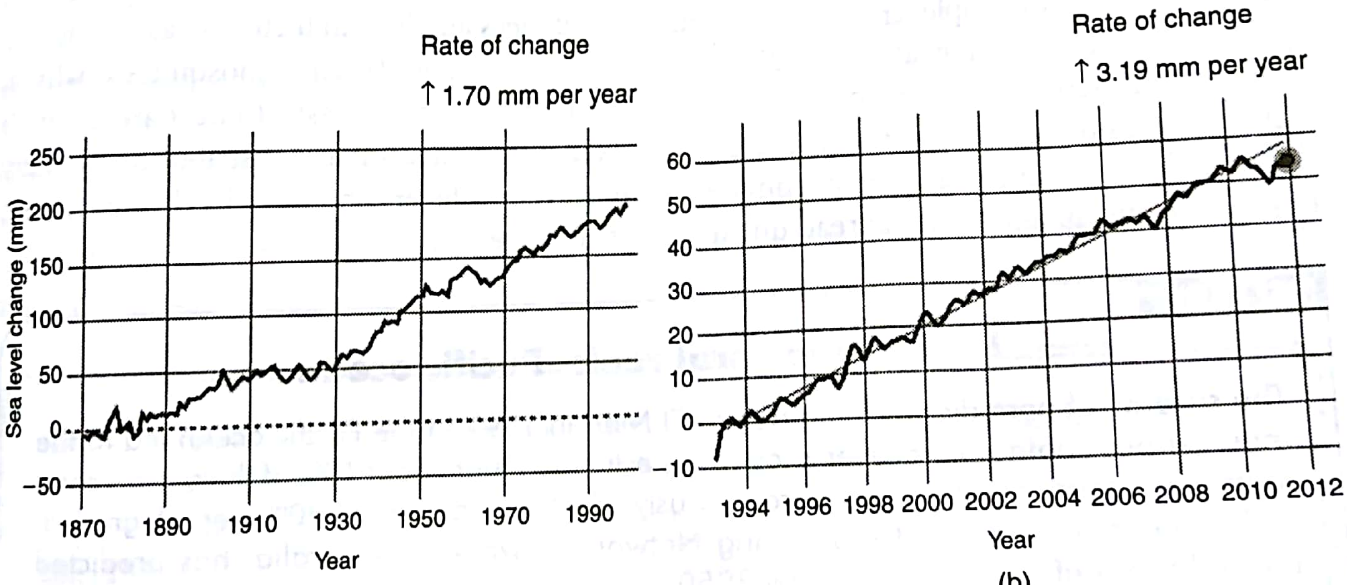
(a) (b)

Fig. 6.6 Land ice: (a) Antarctica (mass variation since 2002; Data source: Ice mass measurement by NASA's grace satellites; Credit: NASA/University of California, irvine) (b) Greenland (mass variation since 2002; Data source: Ice mass measurement by NASA's grace satellites; Credit: NASA/University of California, irvine)

Note: In the above charts, mass change is relative to the average during the entire period.

Sea level rise

Sea level rise is caused by the expansion of sea water as it warms up in response to climate change and the widespread melting of land ice. Figure 6.7(a) shows historical sea level data derived from coastal tide gauge records (trend calculated using the linear regression method) and Fig. 6.7(b) shows the average sea level since 1993 derived from global satellite measurements.



(a) (b)

Fig. 6.7 Sea level (a) Ground data (1870–2000; Data source: Coastal tide gauge records; Credit: CSIRO) (b) Satellite data (1993–present; Data source: Satelite sea level observations; Credit: CLS/Cnes/Legos)

The above evidence lay to rest all debates about the phenomena of climate change. Projections of future climate change are derived from a series of experiments made by computer-based global climate models. These are calculated based on factors such as future population growth and energy use. Climatologists of the Intergovernmental Panel on Climate Change (IPCC) have reviewed the results of several experiments in order to estimate changes in climate in the course of this century. These studies have shown that in the near future, the global mean surface temperature will rise by 1.4–5.8°C. This 'warming' will be greatest over land areas and at high latitudes. The projected rate of warming is greater than that observed in the last 10,000 years. The frequency of weather extremes is likely to increase, leading to floods or drought. There will be fewer cold spells but more heat waves. The frequency and intensity of the *El Niño* is likely to increase. The global mean sea level is projected to rise by 9–88 cm by the year 2100. More than half of the world's population now lives within 60 km of the sea. They are likely to be seriously impacted by the ingress of salt water and by the rising sea. Some of the most vulnerable regions are the Nile delta in Egypt, the Ganges–Brahmaputra delta in Bangladesh and many small islands including the Marshall Islands and the Maldives (WHO, 2001).

Human societies will be seriously affected by extremes in climate such as droughts and floods. A changing climate would bring about changes in the frequency and/or intensity of these extremes. This is also a fundamental concern for human health. To a large extent, public health depends on safe drinking water, sufficient food, secure shelter and good social conditions. All these factors are affected by climate change. Freshwater supplies may be seriously affected, reducing the availability of clean water for drinking and washing during drought as well as floods. Water can be contaminated and sewage systems may be damaged. The risk of spread of infectious diseases such as diarrheal diseases will increase. Food production will be seriously reduced in vulnerable regions directly and also indirectly through an increase in pests and plant or animal diseases. The local reduction in food production would lead to starvation and malnutrition with long-term health consequences, especially for children. Food and water shortages may lead to conflicts in vulnerable regions. Climate change-related impacts on human health could lead to displacement of a large number of people, creating environmental refugees and lead to further health issues.

Changes in climate may affect the distribution of vector species (such as mosquitoes) which, in turn, will increase the spread of disease, such as malaria and filariasis, to new areas which lack a strong public health infrastructure. The seasonal transmission and distribution of many diseases that are transmitted by mosquitoes (dengue, yellow fever) and by ticks (Lyme disease, tick-borne encephalitis) may spread due to climate change.

CASE STUDY 7

Damage to coral reefs, Pacific ocean

The severity of periodic warming due to *El Niño* in 1997 in the Pacific ocean led to the most serious death in coral ever known. It is estimated that about 10% of the earth's coral reefs were dead, another 30% were seriously affected and another 30% were degraded.

The Global Coral Reef Monitoring Network, Townsville, Australia, has predicted that all the reefs could be dead by 2050.

Butterfly populations in the United Kingdom

Global warming is leading to an early arrival of butterflies in Britain. Scientists say that butterflies can now be spotted much earlier every year in the last two decades. Some, like the Red Admiral, can now be seen a month earlier than was the case in the mid-1970s. Others, like the Peacock and the Orange Tip, are appearing between 15 and 25 days earlier than in the past. Future rise in temperature is likely to have a detrimental effect on these butterflies. Some butterflies which need cooler temperatures might suffer.

A Task Group set up by WHO has warned that climate change may have a serious impact on human health. Climate change will increase existing health problems and may also bring new and unexpected ones. Strategies aimed at reducing potential health impacts of anticipated climate changes should include the monitoring of infectious diseases and disease vectors to detect early changes in the incidence of diseases and the geographical distribution of vectors; environmental management measures to reduce risk; disaster preparedness for floods or droughts and their health-related consequences. It will be necessary to educate and create early warning systems for epidemic preparedness. Improved water and air pollution control will become increasingly essential for human health. Public education will have to be directed at changes in personal behaviour. The training of researchers and health professionals is essential towards the world becoming more responsible for the expected outcome of Global Climate Change (GCC).

6.6.2 Global Warming

About 75% of the solar energy reaching the earth is absorbed by the earth's surface, which leads to an increase in its temperature. The rest of the heat radiates back to the atmosphere. Some of the heat is trapped by greenhouse gases (GHGs), mostly carbon dioxide. As carbon dioxide is released by various human activities, the amounts are rapidly increasing. This is causing global warming.

The average surface temperature is about 15°C. This is about 33°C higher than it would be in the absence of the greenhouse effect. Without such gases, most of the earth's surface would be frozen with a mean air temperature of –18°C.

Human activities during the last few decades of industrialisation and population growth have polluted the atmosphere to the extent that it has begun to seriously affect the climate. The carbon dioxide in the atmosphere has increased by 31% since pre-industrial times, causing more heat to be trapped in the lower atmosphere. There is evidence to show that carbon dioxide levels are still increasing. Many countries have signed a convention to reduce GHGs under the United Nations Framework Convention on Climate Change (UNFCC). However, the current international agreements are not still effective enough to prevent significant changes in climate and a rise in sea levels.

Global warming is accelerating faster than that calculated by climatologists a few years ago. In 1995, the IPCC predicted that global warming would raise temperatures by 3.5–10°C during the 21st century, if the present trends continue. It is now believed that the raise could be much greater. This would lead to not only to changes in temperature but also the amount of rainfall. India may see great annual fluctuations in rainfall leading to floods and droughts.

6.6.3 Acid Rain

When fossil fuels such as coal, oil and natural gas are burned, chemicals like sulphur dioxid and nitrogen oxides are produced. These chemicals react with water and other chemicals in th air to form sulphuric acid, nitric acid and other harmful pollutants like sulphates and nitrate

These acid pollutants spread upwards into the atmosphere and are carried by air currents, to finally return to the ground in the form of acid rain, fog or snow. The corrosive nature of acid rain causes many forms of environmental damage. Acid pollutants also occur as dry particles and gases, which when washed from the ground by rain, add to the acids in the rain to form an even more corrosive solution. This is called acid deposition.

Damage from acid rain is widespread in North America, Europe, Japan, China and South-east Asia. In the US, coal-burning power plants contribute to about 70% of sulphur dioxide. In Canada, oil refining, metal smelting and other industrial activities account for 61% of the sulphur dioxide pollution. Motor vehicle exhaust fumes are the main source of nitrogen oxides. The acids in acid rain chemically react with any object they come into contact with.

Effects

- Acid rain dissolves and washes away nutrients in the soil, which are needed by plants. It can also dissolve naturally occurring toxic substances like aluminum and mercury, freeing them to pollute water or poison plants.
- Acid rain indirectly affects plants by removing nutrients from the soil in which they grow. It affects trees more directly by creating holes in the waxy coating of leaves, causing brown dead spots which affect the plant's photosynthesis. Such trees are also more vulnerable to insect infestations, drought and cold. Spruce and fir forests at higher elevations seem to be most at risk. Farm crops are less affected by acid rain than forests.
- Acid rain that falls or flows as ground water to reach rivers, lakes and wetlands, causes the water in them to become acidic. This affects plant and animal life in aquatic ecosystems.
- Acid rain also has far reaching effects on wildlife. By adversely affecting one species, the entire food chain is disrupted, ultimately endangering the entire ecosystem. Different aquatic species can tolerate different levels of acidity. For instance clams and mayflies have a high mortality when water has a pH of 6.0. Frogs can tolerate more acidic water, although with the decline in supply of mayflies, frog populations may also decline. Land animals that are dependent on aquatic organisms are also affected.
- Acid rain and dry acid deposition damages buildings, automobiles and other structures made of stone or metal. The acid corrodes the materials causing extensive damage and ruins historic buildings. For instance the Parthenon in Greece and the Taj Mahal in India have been affected by acid rain.
- Although surface water polluted by acid rain does not directly harm people, the toxic substances leached from soil can pollute the water supply. Fish caught in these waters may be harmful for human consumption. Acid, along with other chemicals in the air, produces urban smog, which causes respiratory problems.

The best way to stop the formation of acid rain is to reduce the emissions of sulphur dioxide and nitrogen oxides into the atmosphere. This can be achieved by using less energy from fossil fuels in power plants, vehicles and industries. Switching to cleaner burning fuels is also a way out. For example, using natural gas which is cleaner than coal or using coal with lower sulphur content. Developing more efficient vehicles will reduce pollutants from being released into the air. If pollutants have already been formed by burning fossil fuels, they can be prevented from entering the atmosphere by using scrubbers in the smokestacks of factories. These spray a mixture of water and limestone into the polluting gases, recapturing the sulphur.

In catalytic converters, the gases are passed over metal coated beads that convert harmful chemicals into less harmful ones. These are used in cars to reduce the effects of exhaust fumes on the atmosphere. Once acid rain has affected soil, powdered limestone can be added to the soil by a process known as liming to neutralise the acidity of the soil.

6.6.4 Ozone Layer Depletion

Ozone is formed by the action of sunlight on oxygen. It forms a layer 20–50 kms above the surface of the earth. This action takes place naturally in the atmosphere, but is very slow. Ozone is a highly poisonous gas with a strong odour. It is a form of oxygen that has three atoms in each molecule. It is considered a pollutant at ground level and constitutes a health hazard by causing respiratory ailments like asthma and bronchitis. It also causes harm to vegetation and leads to a deterioration of certain materials like plastic and rubber. Ozone in the upper atmosphere however, is vital to all forms of life as it protects the earth from harmful UV radiations of the sun. The ozone layer in the upper atmosphere absorbs the UV radiation, preventing it from reaching the earth's surface.

In the 1970s, scientists discovered that chemicals called chlorofluorocarbons or CFCs, which are used as refrigerants and aerosol spray propellants, pose a threat to the ozone layer. The CFC molecules are virtually indestructible until they reach the stratosphere, where UV radiation breaks them down to release chlorine atoms. These chlorine atoms react with ozone molecules to break them down into oxygen molecules. These oxygen molecules do not absorb UV radiation. Since the early 1980s, scientists have detected a thinning of the ozone layer in the atmosphere above Antarctica. This phenomenon is now being detected in other places as well, including Australia.

The destruction of the ozone layer causes increased incidence of skin cancer and cataracts. It also causes damage to certain crops and plankton, thus affecting natural food chains and food webs. This decrease in vegetation leads to an increase in carbon dioxide.

With the signing of the Montreal Protocol in 1987, a treaty for the protection of the ozone layer, the use of CFCs was to be banned by the year 2000, after which the ozone layer is expected to slowly recover over a period of about 50 years. Although the use of CFCs has been reduced and is now banned in most countries, other chemicals and industrial compounds such as bromine, halocarbons and nitrous oxides from fertilisers continue to attack the ozone layer.

6.6.5 Nuclear Accidents and Nuclear Holocaust

Nuclear energy was researched and developed by man as an alternate source of clean and cheap energy compared to fossil fuels. Although this did happen, along with the benefits of nuclear energy came its downfalls. In the short history of nuclear energy, there have been a number of accidents that have surpassed any natural calamities or other energy source extractions in their impact. A single nuclear accident causes loss of life, long-term illnesses and destruction of property on a large scale and for a long period of time. Radioactivity and its fallout lead t cancer, genetic disorders and death in the affected area for decades after the accident, thu affecting all forms of life for several generations.

The use of nuclear energy in war has had devastating effects on humans and on the eart In the only use of nuclear power in war, the United States dropped two atomic bombs over th

CASE STUDY 8

Nuclear disasters and leakages

In 1986, the Nuclear Power Station at Chernobyl in the erstwhile USSR developed a problem that led to a fire and a number of explosions in its nuclear reactor. The radioactive dust spread over many kilometers and covered not only Europe but North America as well. Three people died in the explosion and 28 shortly after due to radiation exposure. Around 259 sick people were hospitalised. As the area had to be evacuated, 1,35,000 people had to be moved immediately and another 1.5 lakh by 1991. As radioactive fall-out continued, even more people had to be moved. An estimated 6.5 lakh people may have been seriously affected. They could get cancer, thyroid tumours, cataracts and suffer from a lowered immune mechanism. Sheep in Scotland and reindeer in Lapland were affected and were unfit for human consumption since radioactivity passed from grass to these herbivores. Vegetables, fruit and milk were contaminated in Europe.

Japanese towns of Hiroshima and Nagasaki in 1945. These two atomic bombs killed thousands of people, left many more thousands injured and destroyed everything for miles around. The effects of the radiation from these nuclear bombs can still be seen today in the form of cancer and genetic mutations in the affected children and survivors of the incident.

6.7 WASTELAND RECLAMATION

Loss of vegetation cover leads to loss of soil through erosion, which ultimately creates wastelands. This is one of the pressing problems of our country as loss of soil has already ruined large amounts of cultivable lands. If it remains unchecked, it will affect the remaining lands. Unless we adequately safeguard our 'good' lands, we may eventually face a serious shortage of foodgrains, vegetables, fruit, fodder and fuelwood. Hence, conservation of soil, protecting the existing cultivable lands and reclaiming the already depleted wastelands figure prominently among the priority tasks of planning for the future. Unfortunately, some wasteland reclamation programs have been unsuccessful as reclaimed lands have reverted to their original poor condition, due to mismanaged and unscientific methods of reclamation.

In choosing wasteland reclamation methods, attention must be paid to the cost factor. A proper study of environmental aspects and human impact which are responsible for the development of wastelands must also be made.

Wastelands can be classified into: (i) easily reclaimable, (ii) reclaimable with some difficulty, and (iii) reclaimable with extreme difficulty.

Easily reclaimable wastelands can be used for agriculture. Those which can be reclaimed with some difficulty can be utilised for agro-forestry. Wastelands that are reclaimed with extreme difficulty can be used for forestry or to recreate natural ecosystems.

Wastelands can be reclaimed for agriculture by reducing the salt content in the soil which can be done by leaching and flushing. Gypsum, urea, potash and compost are added before planting crops in such areas.

Agro-forestry involves putting land to multiple uses. It implies the integration of trees with agricultural crops or livestock management simultaneously. Its main purpose is to have trees and crops interspersed to form an integrated system of biological production within a certain area. Attempts to grow trees in highly alkaline saline soils have been largely unsuccessful. Field experiments have shown that species like eucalyptus, *Prosopis* and *Acacia nilotica* cannot be grown in highly alkaline soil. Studies have shown that if tree seedlings are planted with a mixture of original soil, gypsum and manure, better growth can be achieved. It is, however, preferable to use indigenous species of trees so that the program recreates the local ecosystem with all its constituent species.

Need for Wasteland Development

Wasteland development provides a source of income for the rural poor. It ensures a constant supply of fuel, fodder and timber for local use. It makes the soil fertile by preventing soil erosion and conserving moisture. The program helps maintain an ecological balance in the area; the increasing forest cover maintains the local climatic conditions; the regenerated vegetation cover helps in attracting birds which feed on pests in the surrounding fields and function as natural pest controllers; and the trees help in holding moisture and reducing surface run-off rates thus controlling soil erosion.

Process of Wasteland Reclamation

The problem needs to be identifed at the micro-level. For this, district, village and plot-level surveys of the wasteland are necessary. A profile of the maps indicating the detailed distribution and information on the wasteland is essential. With the help of local government institutions such as the village *panchayats*, along with Block Development officers and Revenue Department functionaries, a plan based on the community's needs must be produced. This must be a participatory exercise, involving all the different stakeholders in the community. A think-tank of administrators, ecologists and local NGOs must also be involved in the process. Next, the factors that are responsible for the formation of wastelands should be identified. Based on these factors the wasteland is classified into marginally, partially or severely deteriorated lands. Once this is done, the steps to be followed are:

- Locale-specific strategies for reclaiming the wasteland must be worked out. Government officials along with the local NGOs must assist the farmers by demonstrating improved methods of cultivation, arranging for loans for the small, marginal and landless farmers and the people from the weaker sections of society.
- Involving the local women will prove to be of great value.
- Publicity campaigns integrated with training farmers and frontline government and Forest Department staff on the various aspects of wasteland utilisation should be organised.
- Environmental scientists can help by suggesting necessary changes in cropping patterns particularly for drought prone areas.
- Selection of appropriate crops for fodder and trees that provide local people with NTFPs according to the nature of the wasteland should be done.
- Soil must be tested in laboratories to provide guidance to the farmers on the proper land management techniques to be employed.
- Newer technological advances in irrigation and other expertise for improving productivity without creating unsustainable patterns of development should be provided to the local people, especially the weaker sections and landless farmers.

- Guidelines to control water logging must be provided.
- Collective efforts have to be made to check soil losses through water and wind erosion and to prevent the collapse of the irrigation system through siltation.

It is important that plans concerning wasteland reclamation and utilisation prepared at various stages must be properly integrated for a successful long-term outcome. The demands of our increasing human population for environmental goods and services have imposed severe pressures on the available land resources, especially on the forests and green cover. This is closely linked to the well being of the rural population that constitutes a large percentage of the people who depend on local natural resources for their survival. Thus the development of agroforestry-based agriculture and forestry has become the prime prerequisite for the overall development of economy in the country. The pressure on the land is already very high and the only hope of increasing productivity lies in bringing appropriate improvement in the various categories of wasteland spread over the country.

CASE STUDY 9

Tehri, Uttar Pradesh

Nagchaund village, in the Tehri District of Uttar Pradesh, was once an eroded and deforested land. When Soban Singh Bhandari returned to his village after retirement from the army in 1987 he was struck by this degradation. After six months he became the *pradhan* of the village and decided to implement various village development schemes in a different manner. Through the *Jawahar Rozgar Yojana*, he gained immense community support. In 1990, the Forest Department selected a barren 30 ha piece of community land for a micro-watershed development program. The villagers controlled grazing in the area, undertook plantations for fuel and fodder. Bhandari helped the village raise money by selling the fodder from the area to a neighbouring village and the money was used for development and maintenance work. This community effort has had a great impact on the ecology of the area. The moisture content of the area increased and the water sources of the villages were recharged. Local people now have access to all the natural resources they need for their daily lives.

6.8 CONSUMERISM AND WASTE PRODUCTS

Modern societies that are based on using large amounts of goods, especially those that are manufactured for one-time use, are extremely wasteful. The current consumption patterns are depleting non-renewable resources, polluting and degrading ecosystems and altering the natural processes on which life depends. People in the industrialised countries make up 20% of the world population but consume 80% of the world's resources and produce 80% of wastes.* This is due to a pattern of economic development which ensures that people go on consuming more than they actually need. India is rapidly moving into this unsustainable pattern of economic growth and development. It is seen that today's consumption patterns are not only depleting natural resources at a rapid rate, but are also widening the inequalities in consumption in differen societies. Money is not the only way to measure the cost of an item that we use. When on adds up all the raw material and energy that goes into the manufacture of goods or the services provided by nature that one uses during a day's activities, the toll on the environment is large. When this cost is multiplied over a lifespan, the amount is staggering. If one considers the over-utilisation in each family, city or a country, the impact is incredibly high. For example, two hundred billion cans, bottles, plastic cartons and paper cups are thrown away each year in the developed world. Disposable items greatly increase this waste. Rather than compete on quality or reliability, many industrial consumer products are made for one-time use.

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* Demirabas, Ayhan, Global renewable energy resources, Energy sources, Part A: Recovery, utilization and environmental effe 28.8 (2006), 779–792.

So, how can we resist consumerism and decrease waste?

- By buying quality products that are warranted against failure or wearing out,
- By learning about the raw materials that things are made of, with an appreciation of their origin from nature's storehouse,
- By knowing and being sensitive to the conditions of the workers who make them.

While there may be some new appliances and cars that are more productive and energy-efficient, discarding the old often leads to an almost total waste of the energy and material already invested in these products. This alone may more than nullify the energy savings of the new product. This is a tricky problem.

CASE STUDY 10

Himachal Pradesh was the first State in India to regulate the manufacture and use of plastics. The state proposed a ban on all types of polythene packing.

Consumerism is related to the constant purchasing of new goods, with little attention to their true need, durability, origin, or the environmental consequences of their manufacture and disposal. It is driven by huge sums spent on advertising designed to create both a desire to follow trends and a personal feeling of satisfaction based on acquisition.

Consumerism interferes with the sustainable use of resources in a society by replacing the normal desire for an adequate supply of life's necessities with an insatiable quest for things that are purchased by larger and larger incomes. There is little regard for the true utility of what is bought. An intended consequence of this strategy, which is promoted by those who profit from consumerism, is to accelerate the discarding of the old, either because of lack of durability or a change in fashion. Especially in developed countries, landfills are being rapidly filled with discarded products that are cheap, fail to work within a short time of purchase and cannot be repaired. In many cases, consumer products are made psychologically obsolete by the advertising industry long before they actually wear out.

The increasing demands of consumption on the finite resources of the planet, increasing level of environmental pollution and the problems of waste disposal must be changed to the careful utilisation of resources, recovery of used material by waste recycling. Therefore, the reuse of goods and waste utilisation should become a part of the production–consumption cycle. Current patterns in the industrial sector have led to the disposal of waste in a careless and uneconomical manner. For example, it is estimated that the per capita production of domestic waste is many times higher in a developed country when compared to a developing country. Unfortunately, many developing countries are now working out similar wasteful trends throug development, but do not have the same economic potential to handle the waste this new unsustainable strategy produces. Large quantities of solid, liquid and gaseous waste is produced by urban industrial communities in the form of plastic, paper, leather, tin cans, bottles, mineral refuse and pathological waste from hospitals. Dead animals, agricultural wastes, fertiliser and pesticide overuse, and human and animal excreta are essentially rural concerns. The waste is either discharged into the atmosphere, into water sources or buried underground. These wastes are not considered to have any economic value. This attitude towards waste has led to disastrous effects on the environment besides the overexploitation of natural resources.

6.8.1 Reduce, Reuse, Recycle

Reduce, Reuse, Recycle, or the 3Rs principle is a concept in waste management. But what does it actually mean?

Reduce

Although some waste is inevitable in any society, we must minimise the generation of waste at the source by using minimal resources. Do not use what you do not need. The goal of every society should be to reach a low-waste or no-waste society. For example, the fancy packaging of consumer products in two or three layers is not necessary. Further, you can use your own reusable cloth/jute bags instead of plastic bags.

Reuse

The residual waste can be converted into a usable resource. In developed countries waste is used to produce energy. Several technological breakthroughs have recently been made to recover material from industrial waste (such as heavy metals) and chemicals (such as mercury and nitric acid). Thus, the waste does not remain a waste product anymore, but becomes a useful resource; for example, kitchen wet waste to make compost that can be used as an organic fertiliser or using sewage in a biogas plant to make fuel. The waste from one industry could be a valuable resource for another industry. For example, cloth rags from the textile industry are bought and used by paper and other industries; bagasse, a waste product of the sugar industry, is used in the paper and ply industries; the left-over material after the extraction of oil from seeds is used as cattle feed.

Recycle

The generated waste or discarded material that cannot be used again in its original form can be sent back to the industry to be broken down and used as a resource to be made into a new product of the same type or into something entirely different. For example, plastic items are recycled into new plastic products; metal scrap and broken glass is used to make new metal products.

- Finally, the waste material that can neither be reused nor recycled must be disposed of in a proper manner with minimum impact to the environment.
- Non-toxic solid waste should be properly segregated and disposed of in landfills that are properly sealed to avoid leakage and contamination of surrounding land and groundwater.
- Toxic wastes should be treated or disposed of separately in a proper manner.
- Sewage and industrial wastewater should be adequately treated and raw materials recovered from it where possible before it is released into our rivers and waterways.

The 3R principle of Reduce, Reuse, Recycle, should be followed in this order:

- Reduction is the best option. If we reduce at source, there is a smaller chance of waste generation and the pressure on our already stretched natural resources is reduced.
- Reuse is the next best option, as the product is reused in its current form without any energy expended to convert it into a new item.
- Recycling is the last option, as although it converts a waste into a resource, it uses energy to transform that resource into a new usable product.

Thus, by following the 3R principle, that is, by reducing use at source, by reusing and recycling whatever possible and finally by proper disposal of residual waste, we can cut down on the waste generated and ensure that the minimal residual waste does not harm our environment. This principle can be followed by everyone, from an individual or an industry to a whole country.

6.8.2 What can an Individual Do?

You can follow the 3R principle in the following ways:

- Use only as much as you need, be it any resource—water, food, paper and others.
- Next time you throw away something, think about whether it is really a waste. If it is of no use to you, could someone else use it? Reuse kitchen waste water to water your garden, donate old clothes to the needy, instead of throwing them away.
- If you are sure the item is not usable in its present form, can it be recycled? Paper, plastics, glass and metal can all be recycled.
- Segregate your waste into wet and dry garbage. Wet garbage includes most kitchen waste (scraps and waste food). Most of this can be used for composting, while most dry garbage is recyclable.
- The amount of dry waste generated in your household is an indicator of how well you are following the 3R principle. A lot of dry waste means you should go back to the 'Reduce and Reuse' principles and try to follow them better.
- As far as possible, avoid using of non-biodegradable materials such as styrofoam and certain types of plastics. Although most plastics are recyclable, recycling still takes up energy, which is another precious resource not to be wasted. If thrown away as waste, styrofoam and plastics can take hundreds of years to decompose.
- Do not litter or throw garbage in public places. Garbage and litter is a visual contaminant and can cause diseases and health problems. The proper disposal of garbage is an important part of waste management.
- Be a conscious consumer and do not buy products that are over-packaged. Try choosing products that are made from recycled material or that are organically grown.

6.9 THE ENVIRONMENT (PROTECTION) ACT

The Environment (Protection) Act, 1986 not only has important constitutional implications but also an international background. The spirit of the proclamation adopted by the United Nations Conference on Human Environment, held in Stockholm in June 1972, was implemented by the Government of India in the form of this Act.

Although there were several existing laws that dealt directly or indirectly with environmental issues, it was necessary to have a general legislation for environmental protection because the existing laws focussed on very specific types of pollution, or specific categories of hazardous substances, or were indirectly related to the environment through laws that control land use, protect our national parks and sanctuaries and our wildlife. However, there was no overarching legislation and certain areas of environmental hazards were not covered. There were also gaps in areas that were potential environmental hazards and there were several inadequate links in handling matters of industrial and environmental safety. This was essentially related to the multiplicity of regulatory agencies. Thus, there was a need for an authority to study, plan and implement the long-term requirements of environmental safety, and to direct and coordinate a system of appropriate response to emergencies threatening the environment.

This Act was thus passed to protect the environment, as there was a growing concern over the deteriorating state of the environment. As the impact due to degradation of the environment grew considerably, environmental protection became a national priority in the 1970s. While the wider general legislation to protect our environment is now in place, it has become increasingly evident that our environmental situation continues to deteriorate. We need to implement this Act much more aggressively if our environment is to be protected. The presence of excessive concentrations of harmful chemicals in the atmosphere and aquatic ecosystems leads to the disruption of food chains and a loss of species.

Public concern and support is crucial for implementing the EPA. This must be supported by an enlightened media, good administrators, highly aware policy makers, informed judiciary and trained technocrats who together can influence and prevent further degradation of our environment. Each of us has a responsibility to make this happen.

6.10 THE AIR (PREVENTION AND CONTROL OF POLLUTION) ACT

The Government passed this Act in 1981 to clean up our air by controlling pollution. It states that sources of air pollution such as industry, vehicles and power plants are not permitted to release particulate matter, lead, carbon monoxide, sulphur dioxide, nitrogen oxides, volatile organic compounds (VOCs) or other toxic substances beyond a prescribed level. To ensure this, Pollution Control Boards (PCBs) have been set up by the government to measure pollution levels in the atmosphere and at certain sources by testing the air. This is measured in parts per million or in milligrams or micrograms per cubic meter. The particulate matter and gases that are released by industry and by cars, buses and two wheelers is measured by using air-sampling equipment. However, the most important aspect is for people themselves to appreciate the dangers of air pollution and reduce their own potential as polluters by seeing that their own vehicles or the industry they work in reduces levels of emissions.

This Act is created to take appropriate steps for the preservation of the natural resources of the earth which among other things includes the preservation of high quality air and ensures controlling the level of air pollution. The main objectives of the Act are as follows:

- To provide for the prevention, control and abatement of air pollution.
- To provide for the establishment of Central and State Boards with a view to implement the Act.
- To confer the powers to implement the provisions of the Act on the Boards and assign to them functions relating to pollution.

Air pollution is more acute in heavily industrialised and urbanised areas, which are also densely populated. The presence of pollution beyond certain limits due to various pollutants discharged through industrial emission is monitored by the PCBs set up in every state.

Powers and Functions of the Boards

Central board: The main function of the Central Board is to implement the legislations that have been created to improve the quality of air and prevent and control air pollution in the country. The Board advises the Central Government on matters concerning the improvement of air quality and also coordinates activities, provides technical assistance and guidance to State Boards and lays down standards for the quality of air. It collects and disseminates information with respect to matters relating to air pollution and performs functions as prescribed in the Act.

State pollution control boards: The State Boards have the power to advise the State Government on any matter concerning the prevention and control of air pollution. They have the right to inspect any control equipment, industrial plant, or manufacturing process at any reasonable time and give orders to take the necessary steps to control pollution. They are expected to inspect air pollution control areas at intervals or whenever necessary. They are empowered to provide standards for emissions to be laid down for different industrial plants with regard to quantity and composition of emission of air pollutants into the atmosphere. A State Board may establish or recognise a laboratory to perform this function.

Penalties: An industry that produces emissions of air pollutants in excess of the standards laid down by the State Board is liable to pay a penalty. The Board also makes applications to the court for restraining persons causing air pollution. Whoever contravenes any of the provisions of the Act or any order or direction issued is punishable with imprisonment for a term which may extend to three months, with a fine of Rs 10,000 or with both. In the case of continuing offence, an additional fine will be levied which may extend to Rs 5,000 for every day during which such contravention continues after conviction for the first contravention.

What Can an Individual Do to Control Air Pollution?

- When you see a polluting vehicle, take down the number and send a letter to the Road Transport Office (RTO) and the PCB.
- If you observe an industry polluting air, inform the PCB in writing and ascertain if action has been taken.
- Use cars only when absolutely necessary; walk or cycle as much as possible instead of using fossil fuel-powered vehicles.
- Use public transport as far as possible, as more people can travel in a single large vehicle rather than using multiple small vehicles which add to pollution.
- Share vehicle space with relatives and friends; carpooling minimises the use of fossil fuels.
- Do not use air fresheners and other aerosols and sprays that contain CFCs that deplete the ozone layer.
- Do not smoke in a public place. It is illegal and endangers not only your own health but also that of others.
- Coughing can spread bacteria and viruses. Use a handkerchief to prevent droplet infection which is airborne, as it endangers the health of other people.

It is a citizen's duty to report to the local authorities such as the Collector, the PCB and the press about offences made by a polluter so that action can be taken against the offender. It is equally important to prevent and report to the authorities on cutting down of trees, as this reduces nature's ability to maintain the carbon dioxide and oxygen levels. Preventing air pollution and preserving the quality of our air is a responsibility that each individual must support so that we can breathe clean air.

6.11 THE WATER (PREVENTION AND CONTROL OF POLLUTION) ACT

The Government formulated this Act in 1974 to prevent the pollution of water by industrial, agricultural and household wastewater that can contaminate our water sources. Wastewater with high levels of pollutants that enter wetlands, rivers, lakes and the sea are serious health hazards. Controlling the point sources by monitoring levels of different pollutants is one way to prevent pollution. The main objectives of the Water Act are to provide for prevention, control and abatement of water pollution and the maintenance or restoration of the quality of water. It is designed to assess pollution levels and punish polluters. The Central Government and State Governments have set up PCBs to monitor water pollution.

Functions of the Pollution Control Boards

The Government has given the necessary powers to the PCBs to deal with the problems of water pollution in the country. The Government has also suggested penalties for violation of the provisions of the Act. Central and state water-testing laboratories have been set up to enable the Boards to assess the extent of water pollution and standards have been laid down to establish guilt and default. The Central and State Boards are entitled to certain powers and functions which are as follows:

Central Board: It has the power to advise the Central Government on any matter concerning the prevention and control of water pollution. The Board coordinates the activities of the State Boards and also resolves disputes. The Central Board can provide technical assistance and guidelines to State Boards to carry out investigations and research relating to water pollution, and organises training for people involved in the process. The Board organises a comprehensive awareness program on water pollution through mass media and also publishes data regarding water pollution. The Board lays down or modifies the rules in consultation with the State Boards on standards of disposal of waste. The main function of the Central Board is to promote the cleanliness of rivers, lakes, streams and wells in the country.

State Boards: They have the power to advise the State Government on any matter concerning water pollution. It plans a comprehensive program for the prevention of water pollution. It collects and disseminates information on water pollution and participates in research in collaboration with the Central Board in organising training of people involved in the process. The Board inspects sewage or trade effluents, treatment plants, purification plants and the systems of disposal and also evolves economical and reliable methods of treatment of sewage and other effluents. It plans the utilisation of sewage water for agriculture. It ensures that if effluents are to be discharged on land, then the waste is diluted. The State Board advises State Governments with respect to location of industries. Laboratories have been established to enable the Board to perform its functions.

The State Boards have the power to obtain information from officers empowered by it to make surveys, keep records of flow, volume and other characteristics of the water. They are given the power to take samples of effluents and suggest the procedures to be followed in connection with the samples. The concerned board analyst is expected to analyse the sample sent to him and submit a report of the result to the concerned Board. The Board is required to send a copy of the result to the respective industry. The Board also has the power of inspecting any plant record, register, document or any material object and conducting a search in any place in which there is reason to believe an offence has been committed under the Act.

Penalties are charged for acts that have caused pollution. This includes failing to furnish information required by the Board, or failing to inform the occurrence of any accident or other unforeseen act. An individual or organisation that fails to comply with the directions given in the subsections of the law can be convicted or punished with imprisonment for a term of three months, with a fine of Rs 10,000 or both and in case failure continues, an additional fine of Rs 5,000 every day. If a person who has already been convicted for any offence is found guilty of the same offence again, s/he after the second and every subsequent conviction, would be punishable with imprisonment for a term not less than two years but which may extend to seven years with a fine.

What Can Individuals Do to Prevent Water Pollution?

- Inform the PCB of any offender who is polluting water and ensure that appropriate action is taken. One can also write to the press.
- Do not dump wastes into a household or industrial drain which can directly enter any water body, such as a stream, river, pond, lake or the sea.
- Do not use toilets for flushing down waste items as they do not disappear but reappear at other places and cause water pollution.
- Use compost instead of chemical fertilisers in gardens.
- Avoid the use of pesticides such as DDT, Malathion and Aldrin at home; use alternative methods like a paste of boric acid mixed with gram flour to kill cockroaches and other insects. Use dried neem leaves or other natural solutions as cleaning agents and to help keep away insects.

6.12 THE WILDLIFE PROTECTION ACT

This Act, passed in 1972, deals with the declaration of National Parks and Wildlife Sanctuaries and their notification. It establishes the structure of the state's wildlife management and the posts designated for wildlife management. It provides for setting up Wildlife Advisory Boards. It prohibits hunting of all animals specified in Schedules I to IV of the Act. These are notified in order of their danger of extinction. Plants that are protected are included in Schedule VI.

The amendment to the Wildlife Protection Act in 2002 is more stringent and prevents the commercial use of resources by local people. It has brought in new concepts such as the creation of Community Reserves. It has also altered several definitions. For instance, fish are now included under animals. Forest produce has been redefined to ensure the protection of ecosystems.

While there are several changes, the new Act still has serious issues concerning its implementation. Laws are only as good as the ones that can be enforced. The Act is expected to deter people from breaking the law. However, there are serious problems due to poaching. One cannot expect to use the Act to reduce this without increasing forest staff, providing weapons, jeeps and radio equipment to establish a strong deterrent force.

Penalties: A person who breaks any of the conditions of any license or permit granted under this Act shall be guilty of an offence against this Act. The offence is punishable with imprisonment for a term which may extend to three years, a fine of Rs 25,000 or both. An offence committed in relation to any animal specified in Schedule I or Part II of Schedule II, such as the use of meat of any such animal, or animal articles like a trophy, shall be punishable with imprisonment for a term not less than one year and may extend to six years and a fine of Rs 25,000.

In the case of a second or subsequent offence of the same nature mentioned in this sub-section, the term of imprisonment may extend to six years and not less than two years with a penalty of Rs 10,000.

What Can an Individual Do?

- If you observe an act of poaching, or see a poached animal, inform the local Forest Department Official at the highest possible level. One can also report the event through the press. Follow up to check that action is taken by the concerned authority. If no action is taken, one must take it up to the Chief Wildlife Warden of the State.
- Say 'no' to the use of wildlife products and also try to convince other people not to buy them.
- Reduce the use of wood and wood products wherever possible.
- Avoid misuse of paper because it is made from bamboo and wood, the cutting of which destroys wildlife habitats. Paper and envelopes can always be reused.
- Create a pressure group and ask the government to ensure that the biodiversity of our country is conserved.
- Do not harm animals and dissuade others from cruelty to animals.
- Do not disturb birds' nests and fledglings.
- When you visit the zoo do not tease the animals by throwing stones or feeding them and prevent others from doing so.
- If you come across an injured animal, do what you can to help it.
- If the animal needs medical care and expert attention contact the Society for the Prevention of Cruelty to Animals (SPCA) or Blue Cross in your city.
- Create awareness about biodiversity conservation in your own way to family and friends.
- Join organisations which are concerned with protection of biodiversity, such as the Worldwide Fund for Nature–India (WWF–I), Bombay Natural History Society (BNHS) or a local conservation NGO.

6.13 FOREST CONSERVATION ACT

To appreciate the importance of the Forest Conservation Act of 1980, which was amended in 1988, it is essential to understand its historical background. The Indian Forest Act of 1927 consolidated all the previous laws regarding forests that were passed before the 1920s. The Act gave the Government and Forest Department the power to create Reserved Forests, and the right to use Reserved Forests for Government use alone. It also created Protected Forests, in which the use of resources by local people was controlled. Some forests were to be controlled by the village community, and these were called Village Forests.

The Act remained in force till the 1980s when it was realised that protecting forests for timber production alone was not acceptable. Protecting the services that forests provide and its valuable assets such as biodiversity began to overshadow the importance of the revenue earnings from timber. Thus a new Act was essential. This led to the Forest Conservation Act of 1980 and its amendment in 1988.

India's first Forest Policy was enunciated in 1952. Between 1952 and 1988, the extent of deforestation was so great that it became essential to formulate a new policy on forests and their utilisation. The earlier forest policies had focussed only on revenue generation. In the 1980s it became clear that forests must be protected for other functions such as the maintenance of soil and water regimes which are prime ecological concerns. It also provided for the use of goods and services of the forest for its local inhabitants.

The new policy framework made conversion of forests into land for other uses much less possible. Conservation of the forests as a natural heritage finds a place in the new policy, which includes the preservation of its biological diversity and genetic resources. It also values meeting the needs of local people for food, fuelwood, fodder and NTFPs. It gives priority to maintaining environmental stability and ecological balance. It expressly states that the network of Protected Areas should be strengthened and extended.

In 1992, the 73rd and 74th Amendments to the constitution furthered governance through *panchayats*. They allow the states to invest the local *panchayats* with the authority to manage local forest resources.

The Forest Conservation Act of 1980 was enacted to control deforestation. It ensured that forestlands could not be de-reserved without prior approval of the Central Government. This was created as some states had begun to de-reserve the Reserved Forests for non-forest use. These states had regularised encroachments and resettled 'project affected people' from development projects such as dams in these de-reserved areas. The need for a new legislation became urgent. The Act made it possible to retain a greater control over the frightening level of deforestation in the country and specified penalties for offenders.

Penalties for offences in reserved forests: No person is allowed to make clearings or set fire to a Reserved Forest. Cattle are not permitted to trespass into the Reserved Forest. Felling, collecting of timber, bark or leaves, quarrying or collecting any forest product is punishable with imprisonment for a term of six months, with a fine which may extend to Rs 500, or both.

Penalties for offences in protected forests: A person who commits any of the following offences like felling trees, stripping the bark or leaves of trees, setting fire to such forests, kindling a fire without taking precautions to prevent its spreading, dragging timber, or permitting cattle to damage any tree, shall be punishable with imprisonment for a term which may extend to six months or with a fine which may extend to Rs 500, or both.

When there is a reason to believe that a forest offence has been committed pertaining to forest produce, the produce together with all tools used in committing such offences may be seized by a forest officer or police officer. Every officer seizing any property under this section shall put on the property a mark indicating the seizure and report the seizure to the magistrate who has the jurisdiction to try the offence. Any forest officer, even without an order from the magistrate or a warrant, can arrest any person against whom a reasonable suspicion exists.

What Can an Individual Do to Support the Act?

- Be alert to destructive activities in your local green areas such as Reserved Forests and Protected Forests, and in Protected Areas (national parks and wildlife sanctuaries). Report any such act to the Forest Department as well as the press. Reports of violations can be made to the Conservator of Forests, District Forest Officer, Range Forest Officer, Forest Guard, the District Commissioner or local civic body.
- Acquaint yourself with the laws, detailed rules and orders issued by the Government.
- Be in touch with concerned local NGOs and associations. Organise one with other like-minded people if none exist in your area.
- Create awareness about the existence and value of national parks and sanctuaries and build up a public opinion against illegal activities in the forest or disturbance to wildlife.
- Pressurise the authorities to implement forest and wildlife laws and rules to protect green areas.
- Take legal action if necessary and if possible through a Public Interest Litigation (PIL) against the offending party. Use the help of NGOs who can undertake legal action.
- Help to create public pressure to change rules, laws and procedures when necessary.
- Use better, ecologically sensitive public transport and bicycle tracks. Do not litter in a forest area.
- Participate in preservation of greenery by planting, watering and caring for plants.

Whom should Forest Offences be Reported to?

If you as a citizen come across anyone felling trees, encroaching on forest land, dumping garbage, cutting greenwood, lighting a fire, or creating a clearing in Reserved Forests, Protected Forests, National Park, Sanctuary or other forest areas, you must report it to the forest/wildlife officers concerned. For urgent action, one can contact the police. In fact, you should file an FIR in any case because it serves as an important proof that you have made the report.

6.14 ISSUES INVOLVED IN ENFORCEMENT OF ENVIRONMENTAL LEGISLATION

Environmental legislation has evolved to protect our environment as a whole, our health and the earth's resources. The presence of a legislation to protect air, water and soil does not necessarily mean that the problem has been addressed. Once legislation is made at the global, national or state level, it has to be implemented. For environmental legislation to be successfully implemented there has to be an effective agency to collect relevant data, process it and pass it on to a law enforcement agency. If the law or rule is broken by an individual or institution, this has to be punished through the legal process. Information to law enforcement officials must also come from concerned individuals. In most situations, if no cognizance is taken, the interested concerned individual must file a Public Interest Litigation (PIL) for the protection of the environment. There are several NGOs in the country such as WWF-I, BEAG and the BNHS, which take these matters to court in the interest of conservation. Anyone can request them to help in such matters. There are also legal experts such as M C Mehta who have successfully fought cases in the courts to support environmental causes. A related issue is the fact that there are several irregular practices for which a bribe to an unscrupulous official is used to cover up an offence. Thus, the general public must act as a watchdog not only to inform concerned authorities, but also to see that action is taken against offenders.

6.14.1 Environment Impact Assessment (EIA)

For all development projects, whether government or private, the Ministry of Environment and Forests (MoEF) requires an impact assessment to be carried out by a competent organisation. The EIA must look into physical, biological and social parameters. EIAs are expected to indicate what the likely impact could be if the project is passed. The MoEF has identified a large number of projects that need clearance on environmental grounds before they are set up.

So what must a Project's EIA Address?

- An EIA must define the impact of the project on water, soil and air.
- It must list the flora and fauna, including any endangered species in the region and specify if any species whose habitat or life could be adversely affected.
- It must list the impact on the lives of local people if any.

After the Environmental Protection Act of 1986 was passed, an EIA to get an environmental clearance for a project became mandatory. The impact created by each type of industry differs and the proposed sites also vary in their sensitivity to impact. Some areas are more fragile than others, some have unique ecosystems, while others are the wildlife habitats or the home of endangered species of plants or animals. All these aspects require evaluation before a development project or a site for an industry is cleared.

New projects where no development has been done are called ‘green field projects’. Projects that already exist but require expansion must also apply for clearance. These are called ‘brown field projects’.

Project proponents are expected to select a competent agency to undertake an EIA. Projects can be classified into those with a mild impact, a moderate impact or a serious impact. Some may have a temporary major impact, during the construction phase, which could later become less damaging, or be mitigated by a variety of measures. In other situations the impact may continue and even increase, for example, where toxic solid waste will be constantly generated. Some projects could thus cause temporary reversible damage while others can have irreversible or even permanent impact.

Environmental Clearance—What is Involved?

- The proposer of the project is expected to apply to the State Pollution Control Board (PCB).
- The PCB checks and confirms that the EIA can be initiated.

- The agency that does the assessment submits a report to the proposer. This may take several months.
- The report of the Environmental Statement is forwarded to the MoEF, which is the impact assessment authority.

After 1997, the MoEF has stipulated that a public hearing should be done at the local level. The PCB publishes an advertisement about the hearing in the local vernacular press. An Environmental Impact Statement (EIS), which is an executive summary of the EIA, is kept for the public to read. The venue and time of the public hearing is declared.

Once the hearing is held and opinions have been expressed, both for and against the project, the minutes of the meeting are sent to the MoEF.

Drawbacks

Experience shows that a large number of EIAs are inadequately researched and are frequently biased as they are funded by the proposer of the project.

While most EIAs are adequate for studies on the possibilities of air, water and soil pollution, they generally deal inadequately with issues such as the preservation of biodiversity and the social issues that may arise from future environmental impact. Biodiversity concerns frequently are sketchily considered and mostly consist of a listing of species without population assessments, census figures of wildlife or a study of the effects on the ecosystem as a whole. Changes in landuse patterns affect whole communities of living organisms. This is rarely taken into account, as such issues are difficult to assess in quantifiable terms.

Issues related to equity of resources that are inevitably altered by development related projects are also not fully addressed. These cryptic concerns must be dealt with more seriously in environmental assessments and the public at large should know and appreciate these inadequacies. It is crucial that environmental awareness becomes a part of public thinking so that public hearings can be made to a more conscientious audience.

It is not sufficient to say that an EIA has been done. It is the quality and sincerity of the EIA that is of importance. An EIA is not intended to stop all types of development. The site for an industry can be selected carefully and if it is likely to damage a fragile area an alternate, less sensitive area must be selected. In some cases it is essential to drop projects altogether if the anticipated impacts are likely to be very severe. In other cases it is necessary for the project to counter balance its effects by mitigating the ill effects on the environment. This means compensating for the environmental damage by afforestation or creating a Protected Area in the neighborhood at the cost of the project. Rehabilitation and resettlement of the project-affected people is a key concern, which should be given adequate funds and should be done only after consent is clearly obtained from the people living in the area. In most cases it is advisable to avoid resettlement altogether. If an area's vegetation is being affected, the project costs must include the cost of compensatory afforestation and other protective measures.

6.14.2 Citizens Actions and Action Groups

Citizens must learn to act as watchdogs to protect their own environment from the consequences of unsustainable projects around them. Well-informed citizens not only have rights but also have a duty to perform in this regard. They can join action groups to develop a lobby to strengthen the environmental movements in the country, their state, town or village.

Table 6.1 Days with environmental significance

Month	Dates	What you can do
Feb	2; *World Wetland Day*: To raise awareness about wetlands and their importance. This day marks the anniversary of the 1971 Ramsar Convention on Wetlands of International Importance at Ramsar in Iran.	You can initiate a campaign for the proper use and maintenance of wetlands in the vicinity of your city or village.
Mar	21; *World Forestry Day*: To raise awareness about the rapid disappearance of forests.	Initiate an action-oriented program including activities such as tree plantation in your area.
	26; 8.30 pm: *Earth Hour*: To take a stand against climate change by turning off lights for 1 hour in your home and/or business.	Pledge your support for the planet by switching off all lights during Earth Hour.
Apr	7; *World Health Day*: To raise awareness about issues of public and occupational health.	A campaign for personal sanitation and hygiene. Topics that deal with environment-related diseases and their spread can be discussed and preventive measures suggested.
	18; *World Heritage Day*: To protect and preserve our cultural heritage	A visit to a local fort or museum and/or create awareness among the local people about their very valuable heritage sites.
	22; *Earth Day*: To draw attention to increasing environmental problems caused by humans on earth.	This day is now celebrated all over the world with rallies, festivals, clean-ups, special shows and lectures.
Jun	5; *World Environment Day*: A day to stimulate worldwide awareness of environmental issues and encourage political action. This day marks the anniversary of the 1972 Stockholm Conference on Human Environment in Sweden.	This day can be used to project the various environmental activities that a college has undertaken during the year. New pledges must be made to strengthen an environmental movement at the college level.
	11; *World Population Day*: To raise awareness on global population issues.	The vital link between population and environment could be discussed in seminars held at college and other NGOs.
Aug	6; *Hiroshima Day*: To commemorate the dropping of the first atomic bomb on the Japanese city of Hiroshima in 1945.	Could be a day to discuss the impacts and consequences of atom bombs. The Bhopal Gas tragedy and the Chernobyl disaster should also be discussed as examples.
Sep	16; *World Ozone Day*: International day for the preservation of the ozone layer. This day marks the Montreal Protocol signed in 1987 to control the production and consumption of ozone-depleting substances.	A day for students to find out more about the threats to this layer and initiate discussions on how the Montreal Protocol has been a success in mitigating this global threat and how its model could be applied in other international agreements such as the Kyoto Protocol.
	28; *Green Consumer Day*: To create awareness (at a household level) amongst consumers about various environmentally friendly products available in the market.	Students could talk to shopkeepers and consumers about excess packaging and a campaign to use articles which are not heavily packaged could be carried out.
Oct	1 to 7: *Wildlife Week*: To protect and conserve our species and threatened ecosystems.	State Forest Departments usually organise various activities in which every student should take part. A poster display or a street play to highlight India's rich biodiversity can be planned.

adult education, which are all essentially complementary to each other. Green movements can grow out of small local initiatives to become major players in advocating environmental protection to the Government. Policy makers will only work towards environmental preservation if there is a sufficiently large bank of voters that insist on protecting the environment. Orienting the media to project pro-environmental issues is an important aspect as several advertising campaigns frequently have messages that are negative to environmental preservation.

6.15.1 Using an Environmental Calendar of Activities

There are several days of special environmental significance, which can be celebrated in the community and can be used for creating environmental awareness in your vicinity, city or village (Table 6.1).

6.15.2 What Can I Do?

Most of us are always complaining about the deteriorating environmental situation in our country. We also blame the government for inaction. However, how many of us actually do anything about our own environment? You can think about the things you can do that support the environment in your daily life, in your profession and in your community. You can make others follow your environment-friendly actions. A famous dictum is to 'think globally and act locally' to improve your own environment. 'You' can make a difference to our world.

Biodiversity Conservation

A great proportion of the residual wilderness of India is now under great threat. Its unique landscapes are shrinking as the intensive forms of agriculture and industrial growth spreads through a process called 'development'. Modern science has serious doubts about the possibility of the long-term survival of the human race if man continues to degrade natural habitats, extinguishes millions of years of evolution through an extinction spasm and looks only at short-term gains. The extinction of a species cannot be reversed. Once a species is lost, it is gone forever. Future generations will hold us responsible for this great loss.

We frequently forget that we are a part of a great complex web of life and our existence depends on the integrity of 1.8 million species of plants and animals on earth that live in a large number of ecosystems. The following are some of the things you can do to contribute towards our ecological security and biodiversity conservation.

✓ Do

- Plant more trees of local or indigenous species around your home and workplace and encourage your friends to do so. Plants are vital for our survival in many ways.
- If your urban garden is too small for trees, plant local shrubs and creepers instead. These support bird and insect life that form a vital component of the food chains in nature. Urban biodiversity conservation is feasible and can support a limited but valuable diversity of life.
- If you live in an apartment, grow a terrace or balcony garden using potted plants. Window-boxes can be used to grow small flowering plants, which also add to the beauty of your house.
- Whenever and wherever possible, prevent trees from being cut. If it is not possible for you to prevent this, report it immediately to the concerned authorities. Old trees are especially important.

- Insist on keeping our hills free of settlements or similar encroachments. The degradation of hill-slopes leads to severe environmental problems.
- When shopping, choose products with limited packaging. It will not only help cut down on the amount of waste in landfills, but also helps reduce our need to cut trees for paper and packaging.
- Look for ways to reduce the use of paper. Use both sides of every sheet of paper and send your waste paper for recycling.
- Buy recycled paper products for your home; for example, sheets of paper and envelopes.
- Reuse cartons and gift wrapping paper. Recycle newspaper and waste paper instead of throwing it away as garbage.
- Participate in the events that highlight the need for creating sanctuaries and national parks, nature trails, open spaces and for saving forests.
- Support Project Tiger, Project Elephant and other such projects, and join NGOs that deal with environmental protection and nature conservation.

× Don't

- Present flower bouquets, instead give a potted plant and encourage your friends to do so.
- Collect unnecessary pamphlets and leaflets just because they are free.

Habitat Preservation

The rapid destruction of forests and the growth of human habitations and activities have reduced the natural habitats of animals and birds. Loss of habitat is one of the major pressures on several species and has led to the extinction of several rare and endemic species. Many others are seriously threatened. We thus have the responsibility of preserving the remaining habitats and their inhabitants. The following are some 'dos and don'ts' that can help preserve threatened ecosystems.

✓ Do

- Visit forests responsibly. Remember to bring out everything you take in and clean up any litter left by others. Stay on marked trails, and respect the fact that wildlife needs peace and quiet. Study the ecosystem; it gives one a greater sense of responsibility to conserve it.
- Be kind to animals. Stop friends from disturbing or being cruel to wild creatures such as birds, frogs, snakes, lizards and insects. They all perform vital functions for a healthy ecosystem.
- Learn about birds and identify the birds that are common in your area. Understand their food requirements and feeding habits.
- Construct artificial nesting boxes for birds. This will encourage birds to stay in your neighbourhood, even if their nesting habitat is scarce.
- Birds need water to drink and to keep their feathers clean. You can make a birdbath out of a big ceramic or plastic saucer. Having birds around your home, school or college can even help increase species diversity in the area.
- Attract wildlife such as small mammals such as squirrels, to your garden by providing running or dripping water. Make a hole in the bottom of a bucket and poke a string through to serve as a wick. Hang a bucket on a tree branch above your birdbath to fill it gradually with water throughout the day.

- Protect wildlife, especially birds and insects that are insectivorous and live in your neighbourhood by eliminating the use of chemicals in your garden. Instead, use vermicompost and introduce natural pest predators.
- Do your gardening and landscaping using local plants to control the pests in your garden.

× Don't

- Bother, tease, hurt or throw stones at animals in a Protected Area and stop others from doing so. If you see an injured animal contact the forest officials.
- Use articles like leather handbags and lipsticks, which are made from animal products. No wildlife products should be used.
- Kill small animals and insects like dragonflies and spiders, as they act as biological pest-control mechanisms.
- Bring home animals or plants collected in the wild. You could be seriously harming wild populations and the natural ecosystems where they were collected.
- Buy products made from ivory. Elephants are killed for their tusks, which are used to make a variety of ivory products.
- Use any wild animal or plant products that are collected from the wild and have dubious medicinal properties. You may be endangering a species and even your own health.

Soil Conservation

Soil degradation affects us all in some way, either directly or indirectly. There are many ways that each of us can help in solving environmental problems due to the loss of soil. Given below are some dos and don'ts for conserving soil.

✓ Do

- Cover the soil in your farm or garden with a layer of mulch to prevent soil erosion in the rains and to conserve soil moisture. Mulch can be made from grass-clippings or leaf-litter.
- If you plan to plant on a steep slope in your farm or garden, prevent soil erosion by first terracing the area. Terraces help in slowing the rain water running downhill so it can soak into the soil rather than carry the soil away.
- Help prevent soil erosion in your community by planting trees and ground-covering plants that help hold the soil in place. You might organise a group of citizens to identify places that need planting, raise funds, work with the local government to plant trees, shrubs and grasses and maintain them over the long term.
- Add organic matter to enrich your garden soil; for example, compost from kitchen scraps and manure from poultry and cows are good sources of nutrients. Make sure the manure is not too fresh and that you do not use too much. Healthy soil grows healthy plants, and it reduces the need for insecticides and herbicides.
- In your vegetable garden, rotate crops to prevent the depletion of nutrients. Legumes like peas and beans put nitrogen back into the soil.
- Set up a compost pit in your college or garden, so that you can enrich your soil with the organic waste from the kitchen and cut down on the amount of waste it sends to a landfill. Set up buckets in your college or lunchroom where fruit and left-over food can be put. Empty the buckets daily into a compost pit and use the rich compost formed in a few weeks to enrich the soil around the college.

- Encourage your local zoo, farms and other organisations or people that house a large number of animals to provide your community with biofertiliser made from animal manure. This can be composted to make a rich fertiliser and it forms an additional source of income for the animal owners.
- Buy organically-grown produce to help reduce the amount of toxic pesticides used in farms that harm soil organisms. Look for organically-grown produce in your grocery shop or try growing some yourself if you have the space.

× Don't

- Remove the cut grass. Leave it on the lawn or put the clippings in your potted plants. Cuttings serve as moisture-retention mulch and a natural fertiliser.
- Burn leaf litter as it can be carcinogenic. Instead, use leaf litter in composting or as mulch—it is a valuable soil conditioner.
- Use toxic pesticides in your garden—they often kill the beneficial organisms your soil needs to stay healthy.

Conserving Water

Most of India has a good average annual rainfall; however, we still face water shortages nearly everywhere. This is one of the major environmental problems in our country. Conservation of this very precious natural resource is very important and it is the need of the hour. It should start with every individual. It must start with you! The following are some of the things you can do to conserve this precious natural resource.

✓ Do

- Reduce the amount of water used for daily activities; for example, turn off the tap while brushing your teeth to save water.
- Use a bucket to wash your clothes instead of using running water; use a mop to clean your bathroom floors instead of pouring buckets of water to do the same.
- Reuse the rinsing water for house plants. Collect and reuse the water that vegetables are washed in to water the plants in your garden or your potted plants.
- Always water plants in your garden early in the morning to minimise evaporation.
- Soak the dishes before washing them to reduce water and detergent usage.
- Look for leaks in the toilet and bathroom, to save several litres of water a day.
- While watering plants, water only as rapidly as the soil can absorb the water.
- When you need to drink water, take only as much as you need to avoid wastage.
- Saving precious rainwater is very important. Harvest rainwater from rooftops and use it sustainably to recharge wells to reduce the burden on rivers and lakes.
- Replace chemicals like phenyl, strong detergents, shampoo, chemical pesticides and fertilisers used in your home, with environment-friendly alternatives, such as neem and biofertilisers. Groundwater contamination by household chemicals is a growing concern.
- For *Ganesh Chaturthi*, bring home a clay idol instead of a plaster of paris idol and donate it instead of immersing it in the river to reduce river pollution.

× Don't

- Turn your tap on full force, instead maintain a slow flow.
- Have long showers; minimise them to 4 minutes. A 10-minute shower wastes many litres of water in comparison to using water from a bucket.

- Over-water garden plants, water them only when necessary.
- Pollute sources of water or water bodies by throwing waste into them. This is the water you or someone else has to drink!
- Throw waste into toilets because finally it goes into water bodies.

Did you know?

Coal fired power stations use a lot of water to generate electricity. In fact to make a kWh (1 unit) of electricity it requires about 2 litres of water. A typical house in developed nations uses about 50 litres of water per day, just through electricity use, and that is before a tap is even turned on!

Conserving Energy

Many of the mineral resources like coal, petroleum and oil are non-renewable sources of energy. At the current rate of fossil fuel consumption, the present oil reserves on the earth will last only for the next 30–50 years. Crores of rupees are being spent to extract, process and distribute coal, petroleum and electricity. Experiments are being carried out to generate energy from wind and photovoltaic cells. At an individual level, every one of us should try to conserve energy. Given below are some of the things you can do to conserve energy.

✓Do

- Turn off the lights fans and air-conditioning when not necessary.
- Use low voltage lights.
- Use tubelights and energy-saving bulbs (LEDs and/or CFLs) as they consume less electricity.
- Use alternative sources of energy like solar power for heating water and for cooking food.
- Cut down on the use of electrical appliances.
- In summer, shut the windows, curtains and doors early in the morning to keep the house cool.
- Use a pressure cooker as much as possible to save energy.
- Turn off the stove immediately after use.
- Plan and keep things ready before you start cooking.
- Keep the vessels closed while cooking and always use small, narrow-mouthed vessels to conserve energy.
- When the food is almost cooked, switch off the gas stove and keep the vessel closed. It will get completely cooked with the steam already present inside.
- Soak rice and pulses before cooking to reduce cooking time and save fuel.
- Get your family to eat together, it will save re-heating fuel.
- Select a light shade of paint for walls and ceilings as it will reflect more light and reduce electrical consumption.
- Position your reading tables near the window and cut down on your electricity bill by reading in natural light.
- Use a bicycle—it occupies less space, releases no pollutant and provides healthy exercise.
- Try using public transport systems like trains and buses as far as possible.

- Walk rather than drive wherever possible.
- Get your vehicles serviced regularly to reduce fuel consumption and reduce pollution levels.

× Don't

- Use unnecessary outdoor decorative lights.
- Use a geyser during summer; instead, heat water naturally with the help of sunlight.
- Use halogen lamps as they consume a lot of electricity.
- Put food in the refrigerator when it is still hot.

Summary

- Sustainable development was defined in 1987 by the World Commission on Environment and Development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. It expresses the idea of environmental, economic and social equity amongst all in keeping with the world's supply of natural resources.
- Water conservation is the need of the hour. Drip irrigation system, small percolation tanks and rainwater harvesting are effective water conservation methods that can be applied in agriculture and domestic use.
- The management of a single unit of land with its water drainage system is called watershed management. Both soil and water conservation measures must be integrated and applied for a watershed management plan to be successful.
- Environmental ethics looks at the philosophical way of valuing our natural environment. It looks at ownership of resources and the way they are distributed. Environmental ethics expresses a need for equity and respect for all other species that we share the planet with.
- Climate change is used to describe any process that causes changes in the earth's climate. However, today the phrase is most often used to describe artificial global warming. Scientists have estimated that the world will be significantly warmer in this decade. The relatively small amount of warming has led to world-wide impact.
- The condition of the wasteland and the cost factor determines the choice of waste reclamation method. For example, easily reclaimable wastelands can be used for agriculture or agroforestry.
- Wasteland reclamation has several ecological and social benefits. For example, an increase in forest cover not only maintains local climatic conditions but also helps prevent soil erosion. An increase in soil fertility ensures a constant supply of fuel, fodder and/or timber for local use, thus providing a source of income for the rural poor.
- The Environment (Protection) Act, 1986 is an overarching legislation that aims to protect and improve all aspects of the environment. The Air Act, Water Act, Wildlife Protection Act and the Forest Conservation Act aim to respectively protect and improve the specific aspects of the environment.
- It is important to remember that steps towards improving our environment always begin at an individual level. 'You' can make a difference to our world.

Questions

1. What does sustainable development mean to you?
2. Rooftop rainwater harvesting can be done to recharge groundwater. Explain this technique with the help of a conceptual diagram.
3. What are the major aspects of a sound watershed development setup? Technically, how can these aspects be achieved?
4. What do environmental ethics deal with? Mention at least 4 issues/challenges of environmental ethics.
5. What do you understand by climate change? Discuss measures that can be adopted at a personal/community level to combat climate change.
6. Discuss three advantages that can be derived from wasteland reclamation.
7. With the help of examples for each, explain the 3Rs principle of waste management.

Unit 7

Human Population and the Environment

Let's understand

- About population growth and how it varies among nations
- What population explosion is and how to control it
- How human health depends on the environment
- About human rights
- What is value education and why it is necessary
- About HIV/AIDS
- About woman and child welfare
- What the role of information technology in environment and human health is

7.1 POPULATION GROWTH, VARIATION AMONG NATIONS

Human history dates back to at least 3 million years. Our ancestors lived as hunters and gatherers, thus maintaining small numbers, probably less than 10 million. With the development of agriculture, food subsistence was achieved, thus supporting a larger population. By ADE 1, the population grew to 300 million and continued to grow at a moderate rate. The 18th century marked the start of the Industrial Revolution. Human population expanded as the standard of living rose and famines and epidemics decreased in several regions. From 760 million in 1750, the population reached 1 billion by 1800. After World War II, the growth of world population accelerated mainly in the less developed countries. A billion people were added between 1960 and 1970 and then another billion between 1975 and 1987. The 20th century started off with 1.6 billion people and ended with 6.1 billion! It is not the census figures alone that need to be stressed, but an appreciation of this impact on our natural resources. The extent of this depletion is further increased by affluent societies that consume more energy and resources per capita, than less fortunate people.

Figure 7.1 shows the explosive population growth in the last 50 years. From 2.5 billion people in 1950 to 6.5 billion in 2005. By 2050, this number could rise to more than 9 billion.

This explosive growth in the past 200 years has had its impact on (i) the disparity in living standards between nations and within nations, (ii) resource use, and (iii) the environment.

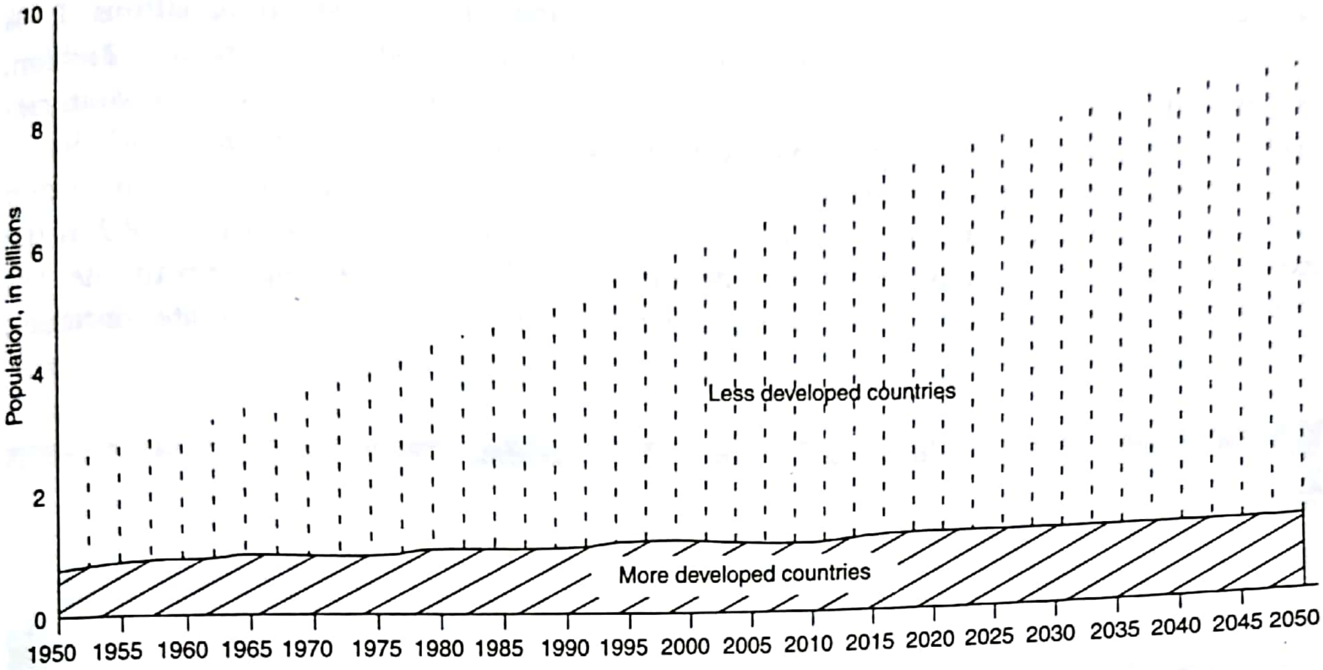

Fig. 7.1 World population growth, 1950–2050
Source: United Nation Population Division, *World Population Prospects,* 2008.

Our landscapes have changed drastically and will continue to change with human population growth. The increasing pressures on resources place great demands on the in-built buffering action of nature that has a certain ability to maintain a balance in our environment. However, current development strategies have led to a breakdown of the earth's ability to replenish the resources on which we all depend.

There are cultural, economic, political and demographic reasons that explain the differences in the rate of population control in different countries. It also varies in different parts of certain countries and is linked with community and/or religious thinking. The lack of Government initiatives for Family Welfare Programmes (FWP) and limited access to a full range of contraceptive measures are some of the serious impediments to limiting population growth in several countries.

7.1.1 Global Population Growth

While the rate at which the world's population is increasing has slowed, the population continues to grow. The rate of the world's annual population change can be expressed as a percentage:

$$\text{Annual rate of natural population change (\%)} = \frac{\text{Birth rate} - \text{Death rate}}{\text{1,000 persons}} \times 100$$

Birth rates and death rates are decreasing worldwide. However, better access to medical care, more widespread immunisation and improved sanitation have meant that death rates have fallen more steeply than birth rates—adding more babies to the world's population. So while the exponential growth rate has declined to a slower rate – from 2.2% to 1.2% – between 1963 and 2005, the same period has seen the population base being almost doubled—from 3.2 billion to 6.5 billion (Miller 2006). Furthermore, the exponential growth rate has been drastically different in developed countries (0.1% annually) compared with developing nations (1.5% annually). This means that the population in developed countries, which is currently 1.2 billion, is expected to change very little in the next 50 years. On the other hand, developing countries will see a steady rise in their population—from 5.3 billion in 2005 to over 8 billion in 2050.

Another measure of population growth is *doubling time*. This is the time taken for a population to double in size. The method to calculate this is by dividing the natural logarithm of 2 by the exponent of growth, or approximated by dividing by 70 by the percentage growth rate. For example, in 2008, the world's population grew by 1.2%. This means that if this rate continues, the world's population will be doubled in approximately 58 years (70/1.2).

Let's do it!

If the population in India is increasing by 1.3% per year, how long will it take for its population to double?

Lets find out

How governments and people from every community meet challenges such as, limiting population size, protecting the natural environment, changing consumer-oriented attitudes, reducing habits that create excessive waste, alleviating poverty and creating an effective balance between conservation and development will determine the world's future.

7.2 POPULATION EXPLOSION: FAMILY WELFARE PROGRAMME

In response to our phenomenal population growth, India seriously took up an effective Family Welfare Programme (FWP) in 1951. This programme's objective is to 'reduce birth rates to the extent necessary to stabilise the population at a level which is consistent with the requirement of the national economy'. Slogans such as *Hum do hamare do* indicated that each family should not have more than two children. The best decision for the method to be used by a couple must be based on good advice from doctors or trained social workers who can suggest the full range of methods available for them to choose from.

Informing the public about the various contraceptive measures that are available is of primary importance. This must be done actively by government agencies such as Health and Family Welfare, as well as education and extension workers. It is of great importance for policy makers and elected representatives of the people – ministers, MPs, MLAs at the central and state levels – to understand the great and urgent need to support the FWP. The media must keep people informed about the need to limit family size and the ill effects of a growing population on the world's resources.

At the global level, in the year 2000, 600 million (or 57%) of women in the reproductive age group were using some method of contraception. However, the use of contraceptive measures is higher in developed countries and lower in developing countries—68% and 55% respectively. Female sterilisation is the most popular method of contraception used in developing countries at present. This is followed by the use of oral contraceptive pills and intrauterine devices (IUDs) for women, and the use of condoms for men. India and China have been using permanent sterilisation more effectively than many other countries in the developing world.

7.2.2 Urbanisation

In 1975, only 27% of the people in the developing world lived in urban areas. By 2000, this had grown to 40% and by 2030, well informed estimates state that this will grow to 56%. The developed world is already highly urbanised with 75% of its population living in urban areas. The urban population growth is both due to migration of people to towns and cities from the rural areas in search of better job opportunities as well as population growth within cities.

As a town grows into a city, it not only spreads outwards into the surrounding agricultural lands or natural areas such as forests, grasslands and wetlands, but also grows skywards with high-rise buildings. The town often loses its open spaces and green cover unless consciously preserved leading to the destruction of the quality of life in urban areas.

Good urban planning is essential for rational landuse, for upgrading slum areas, improving water supply and drainage systems, providing adequate sanitation, developing effective waste water treatment plants and an efficient public transport system.

While all these issues appear to be under the purview of local Municipal Corporations, better living conditions can become a reality only if every citizen plays an active role in managing the environment. This includes a variety of 'Dos and Don'ts' that should become an integral part of our personal lives. Unplanned and haphazard growth of urban complexes has serious environmental impacts. Increasing solid waste, improper garbage disposal and air and water pollution are frequent side effects of urban expansions.

Apart from undertaking actions that support the environment, every urban individual has the ability to influence a city's management. He/she must see that the city's natural green spaces, parks and gardens are maintained, river and water fronts are managed appropriately, roadside tree cover is maintained, hill slopes are afforested, and architectural and heritage sites are protected, Failure to do this leads to increasing urban problems which eventually destroy a city's ability to maintain a healthy and happy lifestyle for its dwellers. All these aspects are closely linked to the population growth in the urban sector. In many cities, population growth often outstrips the planner's ability to respond in time.

A megacity is one which has over 10 million inhabitants. In 1950, there was only one—New York. In 1985, there were five; in 2001, there were fifteen (with Mumbai, Kolkata and Delhi being added to the list from India); as of 2010, there are 25 megacities, 19 of which are in developing countries. By 2015, there will be 36 megacities.

Table 7.1 Megacities in India

Name	Population (in millions) in 2001	Projection (in millions) for 2015
Mumbai	16.5	22.6
Kolkata	13.3	16.7
Delhi	13.0	20.9

Pull and Push Factors

Small urban centers too will grow rapidly during the next decade and several rural areas will require reclassification as urban centers. India's urban areas will grow by a projected 297 million residents. In India, people move to cities from rural areas in the hope of earning better incomes. This is the 'pull' factor. Poor opportunities in the rural sector thus stimulate migration to cities. The loss of agricultural land to urbanisation and industry, the inability of governments to sustainably develop the rural sector and a lack of supporting infrastructure in rural areas—all these factors 'push' people from the agricultural and natural wilderness ecosystems into the urban sector.

As populations in urban centers grow, they draw on resources from more and more distant areas. The *ecological footprint* corresponds to the land area necessary to supply natural resources to a community and disposal of its waste. At present the average ecological footprint of an individual at the global level is said to be 2.3 ha of land per capita. It is estimated though, that the world has only 1.7 ha of land per individual to manage these needs thus leading to an unsustainable use of land.

The pull factor of the urban centers is not only due to better job opportunities, but also better education, health care and relatively higher living standards. During the last few decades in India, improvements in the supply of clean water, sanitation, waste management, education and health care have all been urban centric, even though the stated policy has been to support rural development. In reality, development has lagged behind in the rural sector that is rapidly expanding in numbers. For people living in wilderness areas in our forests and mountain regions, development has been most neglected. It is not appropriate to use the development methods used for other rural communities for tribal people who are dependent on collecting natural resources from the forests. A different pattern of development that is based on the sustainable extraction of resources from their own surroundings would be ideal. In general though, the growing human populations in the rural sector will opt to live where they are only if they are given an equally satisfying lifestyle as they would get in an urban sector.

The wilderness–rural–urban link

Urban centers occupy 2% of the world's land but use 75% of the wood available. About 60% of the world's water is used by urban areas of which half irrigates food crops for urban dwellers, one third goes towards industrial use and the rest for household use and drinking water.

The impact that urban dwellers have on the environment is not obvious to them as it affects distant places which support the urban ecosystem using resources from agricultural and even more remote wilderness ecosystems.

One live in Urban Area.

Urban Poverty and the Environment

The number of poor people living in urban areas is rapidly increasing; a third of all poor people in the world live in urban centers. These people live in urban slums and suffer from water shortages and unsanitary conditions. In most cases, while a slum invariably has unhygienic surroundings, the dwellings themselves are kept relatively clean. It is the common areas used by the community that lacks the infrastructure to maintain a hygienic environment.

One billion urban people in the world live in inadequate housing, mostly in slums, the majority of buildings being temporary structures. However, low income groups that live in high rise buildings can also have high densities and live in poor unhygienic conditions in certain areas of cities. Illegal slums often develop on government land, along railway tracks, on hill-slopes, riverbanks and marshes that are unsuitable for formal urban development. On the riverbanks, floods can render these poor people homeless. Adequate legal housing for the urban poor remains a serious environmental concern.

Urban poverty is even more serious than rural poverty, as unlike in the rural sector, the urban poor, have no direct access to natural resources such as relatively clean river water, fuelwood and NTFPs. The urban poor can only depend on cash to buy the goods they need, while in the rural sector they can grow a substantial part of their own food. Living conditions for the urban poor are frequently worse than for rural poor. Both outdoor and indoor air pollution due to high levels of particulate matter and sulphur dioxide from industrial and vehicle emissions leads to high death rates from respiratory diseases. Most environmental efforts are targeted at reducing outdoor air pollution whereas indoor air pollution, due to the use of fuelwood, waste material and coal in *chulhas*, is an equally major health issue. This can be addressed by using better designed 'smokeless' *chulhas*, hoods and chimneys to remove indoor smoke.

With the growing urban population, a new crisis of unimaginable proportions will develop in the next few years. Crime rates, terrorism, unemployment and serious environmental health-related issues can be expected to escalate. This course of things can only be altered by stabilising population growth on a war footing.

7.3 ENVIRONMENT AND HUMAN HEALTH

Environment-related issues that affect our health have been one of the most important triggers in the increasing awareness of the need for better environmental management. The changes in our environment induced by human activities in nearly every sphere of life have had an influence on our health patterns. The assumption that the only indicator of human progress is economic growth is not true. We expect urbanisation and industrialisation to bring in prosperity, but on the downside, it leads to diseases related to overcrowding and poor quality drinking water, resulting in an increase in water-borne diseases like infective diarrhea and air-borne bacterial diseases like tuberculosis. High-density city traffic leads to an increase in respiratory diseases like asthma. Agricultural pesticides that enhanced food supplies during the green revolution have affected both the farm worker and all of us who consume the produce. Modern medicine promised to solve many health problems, especially associated with infectious diseases through antibiotics, but bacteria have found ways to develop resistant strains, frequently even changing their behaviour in the process, making it necessary to keep on creating newer antibiotics. Many drugs have been found to have serious side-effects. Sometimes, the cure is as damaging as the disease itself.

Thus, development has created several long-term health problems. A better health status of society will bring about a better way of life only if it is coupled with a stabilising population growth.

7.3.1 Environmental Health

Environmental health, as defined by WHO, comprises those aspects of human health, including the quality of life, that are determined by physical, chemical, biological, social and psychosocial factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling and preventing those factors in the environment that adversely affect the health of present and future generations.

Our environment affects health in a variety of ways. Climate and weather affect human health. Public health depends on sufficient amounts of good quality food, safe drinking water and adequate shelter. Natural disasters such as storms, hurricanes and floods still kill many people every year. Unprecedented rainfall triggers epidemics of malaria and water-borne diseases.

Global climate change has serious health implications. Many countries will have to adapt to uncertain climatic conditions due to global warming. As our climate is changing, we may no longer know what to expect. There are increasing storms in some countries, drought in others and a temperature rise throughout the world.

CASE STUDY 1

The El Nino/La Nina–Southern Oscillation (ENSO)

ENSO is a climate pattern that occurs across the Pacific ocean roughly every five years. The changes associated with the El Nino persist for about a year. The atmospheric variations associated with the El Nino and La Nina events are called the Southern Oscillation. Due to global climate change, the number of El Nino events have increased, causing an increase in extreme weather (floods and droughts) in many regions of the world. This also has a strong correlation to the incidence of epidemic diseases. Cycles of malaria in India, Venezuela and Colombia have now been linked to El Nino. Outbreaks of Australian encephalitis (a mosquito-transmitted disease) occur in South-east Australia after heavy rainfall and are associated with La Nina events.

Development strategies that do not incorporate ecological safeguards often lead to ill health, while strategies that can promote health invariably also protect the environment (Fig. 7.2). Thus, environmental health and human health are closely interlinked. An improvement in health is central to sound environmental management. However this is rarely given sufficient importance in planning development strategies.

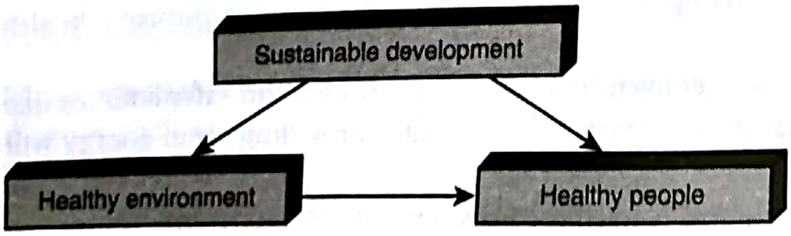

Fig. 7.2 Importance of sustainable development

Examples of the links

- Millions of children die every year due to diarrhea from contaminated water or food. An estimated 2000 million people are affected by these diseases and more than 3 million children die each year from water-borne diseases across the world. In India, it is estimated that every fifth child under the age of 5 dies due to diarrhea (UNICEF—Water, Sanitation and Hygiene 2006). This is a result of inadequate environmental management and is mainly due to inadequate purification of drinking water. Wastewater and/or sewage entering water sources without being treated leads to continuous gastrointestinal diseases in the community and even sporadic large epidemics.
- Millions of people, mainly children, have poor health due to parasitic infections such as amebiasis and worms. This occurs from eating infected food or using poor quality water for cooking food. It is estimated that 36% of children in low-income countries and 12% in middle-income countries are malnourished. In India, about half the children under the age of four are malnourished and 30% of newborns are significantly underweight (World Bank, 2009).
- Hundreds of millions of people suffer serious respiratory diseases, including lung cancer and tuberculosis, from ill-ventilated homes and public places. Motor vehicle exhaust fumes, industrial fumes, tobacco smoke and cooking food on improper *chulhas*, contribute to respiratory diseases.
- Millions of people are exposed to hazardous chemicals in their workplace or homes that lead to poor health due to industrial products where controls are not adhered to.
- Tens of thousands of people in the world die due to traffic accidents owing to inadequate management of traffic conditions. Ineffective first aid at the accident site and the frequent inability to reach a hospital within an hour causes a large number of deaths, especially from head injuries.

Important Strategic Concerns

- Strategies to provide clean potable water and nutrition to all people are an important part of a healthy living environment.
- Providing clean energy sources that do not affect health is a key to reducing respiratory diseases.
- Reducing the environmental consequences of industrial and other pollutants such as transport emissions, can improve public health.
- Changing agricultural patterns to move away from harmful pesticides, herbicides and insecticides which are injurious to the health of farmers and consumers and using alternatives, such as IPM and non-toxic biopesticides, can improve the health of agricultural communities as well as food consumers.
- Changing industrial systems into those that do not use or release toxic chemicals that affect the health of workers and people living in the vicinity of industries can improve health and the environment.
- There is a need to change from using conventional energy to cleaner and safer sources like solar, wind and ocean power that do not affect human health. Providing clean energy will lead to better health.
- Poverty is closely related to health and is itself a consequence of improper environmental management. An inequitable sharing of natural resources and environmental goods and services is linked to poor health.

Definition of health impact assessment (HIA): The WHO defines HIA as a combination of procedures, methods and tools by which a policy, program or project may be judged on the basis of its potential effects on the health of a population and the distribution of those effects within the population. HIA helps decision makers in making choices that promote health by preventing disease/injuries. For example, transport is a major contributor to traffic-related injuries, noise and air pollution. An effective HIA can promote a healthy transport policy/plan that reduces such risks and encourages the use of walking/cycle tracks.

7.3.2 Climate and Health

Centuries of human civilisation have helped mankind to adapt to living in a wide variety of climates—from the hot tropics to the cold arctic, in deserts, marshlands and in the high mountains. Both climate and weather have a powerful impact on human life and health issues.

Natural disasters (heavy rains, floods, hurricanes) can severely affect the health of a community. Poor people are more vulnerable to the health impacts of climate variability than the rich. Of approximately 80,000 deaths which occur world-wide each year as a result of natural disasters, about 95% are in poor countries. In weather-triggered disasters, hundreds of people and animals die, homes are destroyed, crops and other resources are lost. Public health infrastructure, like sewage disposal systems, waste management, hospitals and roads, are damaged. The cyclone in Orissa in 1999 caused 10,000 deaths. The total number of people affected was estimated at 10 to 15 million!

Human physiology can adapt to changes in weather, within certain limits. However, marked short-term fluctuations in weather lead to serious health issues. Heat waves cause heat-related illness and death (heat stroke). The elderly and persons with existing heart or respiratory diseases are more vulnerable. The heat wave in India in 1998 was associated with many deaths.

CASE STUDY 2

European heat wave

The 2003 European heat wave was one of the hottest summers on record, killing more than 35,000 people. France in particular had more than 14,000 heat-related deaths (mostly among elderly) when 7 days of more than 40°C temperatures were recorded between July and August 2003.

Climate plays an important role in vector-borne diseases transmitted by insects like mosquitoes. These disease transmitters are sensitive to the direct effects of climate such as temperature, rainfall patterns and wind. Climate affects their distribution and abundance through its effects on host plants and animals.

7.3.3 Infectious Diseases

Many infectious diseases have re-emerged with a vengeance. The loss of effective control over diseases such as malaria and tuberculosis, have led to a return of these diseases decades after being kept under stringent control. Other diseases, which were not known to science earlier, seem to have suddenly hit our health and our lives during the last few decades.

Two examples of new diseases include Acute Immuno-Depressive Syndrome (AIDS), due to the Human Immunodeficiency Virus (HIV) caused through sexual transmission and Severe

Acute Respiratory Syndrome (SARS). While these cannot be directly related to environmental change, they affect the environment in which we live by forcing a change in lifestyles and behaviour patterns. For example, the SARS outbreak prevented people in several countries from travelling to other countries for months, severely affecting national economies, airline companies and the tourism industry.

Why have infectious diseases that were related to our environment that were under control suddenly make a comeback? Diseases like tuberculosis have been effectively treated with anti-tubercular drugs for decades. These antibiotics are used to kill off the bacteria that cause the disease. However, nature's evolutionary processes permitted the bacteria to mutate by creating new genetically modified strains. These mutated strains, which are not affected by the routinely-used antibiotics, begin to spread rapidly. This leads to a re-emergence of the disease. In the case of tuberculosis, this has led to multi-drug resistant tuberculosis. This is frequently related to HIV, which reduces an individual's immunity to bacteria, such as *mycobacterium tuberculosis* that causes tuberculosis.

The newer broad-spectrum antibiotics, antiseptics, disinfectants and vaccines once thought of as the complete answer to infectious diseases have thus failed to eradicate infectious diseases. In fact, experts now feel that these diseases will be the greatest killers in the future and not diseases such as cancer or heart disease.

While antibiotic resistance is a well-known phenomenon, there are other reasons for the re-emergence of diseases:

- Overcrowding due to the formation of slums in the urban areas leads to several health hazards, including easier spread of respiratory diseases.
- Inadequate drinking water quality, poor disposal of human waste due to the absence of a closed sewage system and poor garbage management are all urban health issues. This has led to the reappearance of diseases such as cholera and an increased incidence of diarrhea and dysentery as well as infectious hepatitis (jaundice).
- Impacts of climate change mean a change in disease patterns and their distribution. For example, warmer climate will change the distribution of dengue, malaria and yellow fever to spread further away from the equator. Warmer, wetter climates could cause serious epidemics of diseases such as cholera. The *El Niño*, which causes periodic warming, is likely to affect rodent populations; this could bring back diseases like the plague.

Globalisation and Infectious Diseases

Globalisation is a world-wide process which includes the internationalisation of communication, trade and economic organisation. It involves parallel changes such as rapid social, economic and political adjustments. Whilst globalisation has the potential to enhance the lives and living standards of certain population groups, for the poor and marginalised populations in both the non-formal as well as formal economic sectors of developing countries, globalisation enhances economic inequalities.

Tuberculosis (TB) kills approximately 2 million people each year (including persons infected with HIV). In India, the disease has re-emerged and is now more difficult to treat. TB is contagious and airborne. It is a disease that affects mostly young adults in their most productive years. Only people who are sick with pulmonary TB are infectious. When infectious people cough, sneeze, talk or spit, they emit the tubercle bacilli into the air. When a healthy person inhales these, she/he gets infected by the disease. The symptoms include prolonged fever, coughing spells and weight loss.

It is estimated that left untreated, each patient of active tuberculosis will infect, on an average, between 10–15 people every year. But people infected with TB will not necessarily get sick with the disease. The immune system can cause the TB bacilli, which is protected by a thick waxy coat, to remain dormant for years. When an individual's immune system is weakened, the chances of getting active TB are greater.

HIV is accelerating the spread of TB. The link between HIV and TB affects a large number of people, each disease speeding the other's progress. HIV weakens the immune system. Someone who is HIV-positive and infected with TB is much more likely to become seriously ill with TB, rather than someone infected with TB who is HIV-negative.

Poorly-managed TB programs are threatening to make TB incurable

Until 50 years ago, there were no drugs to cure tuberculosis. Now, strains that are resistant to one or more anti-TB drugs have emerged. Drug-resistant tuberculosis is caused by inconsistent or partial treatment—when patients do not take all their drugs regularly for the required period, when doctors or health workers prescribe inadequate treatment regimens, or where the drug supply is unreliable. From a public-health perspective, poorly-supervised or incomplete treatment of TB is worse than no treatment at all. When people fail to complete standard treatment regimens, or are given the wrong treatment, they may remain infectious. The bacilli in their lungs may develop resistance to anti-TB drugs. The people that they infect will have the same drug-resistant strain. While drug-resistant TB is treatable, it requires extensive chemotherapy that is often very expensive and is also more toxic to patients.

Malaria

Malaria is a life-threatening parasitic disease transmitted by mosquitoes. The cause of malaria, a single-celled parasite called plasmodium, was discovered in 1880. Later, it was found that the parasite is transmitted from person to person through the bite of the female *Anopheles* mosquito, which requires blood for the growth of her eggs.

At present, approximately 40% of the world's population, mostly those living in the world's poorest countries, risk getting malaria. The disease was once more widespread but it was successfully eliminated from many countries with temperate climates during the mid-20th century. Today, malaria has returned and is found throughout the tropical and sub-tropical regions of the world and causes more than 200 million acute illnesses and at least one million deaths annually (WHO, 2009).

There are several types of human malaria. *Falciparum* malaria is the most dangerous type of infection and is most common in Africa south of the Sahara, where it accounts for extremely high mortality rates. There are also indications of the spread of *P. falciparum* malaria in India and it has reappeared in areas where it had been eliminated.

The malarial parasite enters the human host when an infected *Anopheles* mosquito bites an individual. Inside the human host, the parasite undergoes a series of changes as part of its complex life cycle. Its various stages allow the plasmodia to evade the immune system, infect the liver and red-blood cells, and finally develop into a form that is able to infect a mosquito again when it bites an infected person. Inside the mosquito, the parasite matures until it reaches the sexual stage where it can again infect a human host when the mosquito takes her next blood meal, 10 or more days later.

Malarial symptoms appear about 9–14 days after the mosquito bite, although this varies with different plasmodium species. Malaria produces high fever, headache, vomiting and body ache. If drugs are not available for treatment or the parasites are resistant to them, the infection can progress rapidly to become life-threatening. Malaria can kill by infecting and destroying red blood cells (anemia) and by clogging the capillaries that carry blood to the brain (cerebral malaria) or other vital organs.

Malarial parasites are developing unacceptable levels of resistance to drugs. Besides this, many insecticides are no longer useful against the mosquitoes transmitting the disease.

Measures to prevent malaria:

- Clear pools of stagnant water during the monsoons.
- Use mosquito nets treated with insecticide.
- Prompt access to treatment with effective up-to-date medicines, like artemisinin-based combination therapies (ACTs), saves lives.

7.3.4 Water-Related Diseases

Water supply, sanitation and hygiene development

Globally, about 2.4 billion people live under highly unsanitary conditions. Poor hygiene increases the exposure to risk of incidence and spread of infectious diseases. Water improperly stored in homes is frequently contaminated by inadequate management at the household level. This can be easily reduced through education and awareness about how water-borne diseases are transmitted.

Providing access to sufficient quantities of safe water, facilities for the sanitary disposal of excreta, and introducing sound hygiene-related behaviour can reduce the morbidity and mortality caused by these risks.

Health and water resources development

An important aspect of water-related diseases (in particular, water-related vector-borne diseases) is the way water resources are developed and managed. In many parts of the world, the adverse health impacts of dam construction, irrigation development and flood control is related to increased incidence of malaria, Japanese encephalitis, schistosomiasis, lymphatic filariasis and other conditions. Other health issues indirectly associated with water resources development include nutritional status, exposure to agricultural pesticides and their residues.

Water-borne diseases

Arid areas with rapidly expanding populations are already facing a crisis over water. Conservation of water and better management of existing resources is an urgent need. The demand and supply balance is a vital part of developing the sustainable use of water. This is being termed the 'Blue Revolution' and needs governments, NGOs and people to work together towards a better water policy at the international, national, state, regional and local levels. The present patterns of development are water-hungry and water-wasters. They do not address pollution and overuse. The links between managing water resources and health issues have not been prioritised as a major source of environmental problems that require policy change, administrative capacity building and increased financial support.

There are 4 major types of water-related diseases:

Water-borne diseases: They are caused by dirty water contaminated by human and animal wastes, especially from urban sewage or by chemical wastes from industry and agriculture. Some of these diseases, such as cholera and typhoid, cause serious epidemics. Diarrhea, dysentery, polio, meningitis and hepatitis A and E, are caused due to improper drinking water. Excessive levels of nitrates cause blood disorders when they pollute water sources. Pesticides entering drinking water in rural areas cause cancer, neurological diseases and infertility. Improving sanitation and providing treated drinking water reduces the incidence of these diseases.

Water-based diseases: They are caused by aquatic organisms that live a part of their life cycle in water and another part as a parasite in man, lead to several diseases. In India, guinea worm affects the feet. Round worms live in the small intestine, especially of children.

Water-related vector diseases: They are caused by insects like mosquitoes that breed in stagnant water spread diseases such as malaria and filariasis. Furthermore, changes in climate are leading to the formation of new breeding sites. Other vector-borne diseases in India include dengue fever and filariasis. Dengue fever carries a high mortality; filariasis leads to fever and chronic swelling of the legs. Eliminating mosquito-breeding sites when pooling of water occurs in the monsoon and using fish to control mosquito larval populations, are two ways to reduce these diseases without using toxic insecticides that have ill-effects on human health.

Water-scarcity diseases: In areas where water and sanitation is poor, there is a high incidence of diseases, such as tuberculosis, leprosy and tetanus which occur when one's hands are not properly washed. In other words, the lack of water leads to poor hygiene.

Diarrhea

There are several types of diarrhea, which give rise to loose motions and dehydration. About 4,500 children die *each day* from unsafe water and lack of basic sanitation facilities, mostly in developing countries (UNICEF, 2006).

Effects on health: Diarrhea is the frequent passage of loose or liquid stools and is a symptom of various gastrointestinal infections. Depending on the type of infection, the diarrhea may be watery (as in cholera caused by *Vibrio cholerae*) or passed with blood and mucus (in dysentery caused by an amoeba, *E. histolitica*).

Depending on the type of infection, it may last a few days or several weeks. Severe diarrhea can become life threatening due to the acute loss of fluids and electrolytes such as sodium and potassium, in watery diarrhea. This is particularly fatal in infants and young children. It is also dangerous in malnourished individuals and people with poor immunity.

The impact of repeated diarrhea on nutritional status is linked in a vicious cycle in children; chemical or non-infectious intestinal conditions can also result in diarrhea. There are several causes for the onset of diarrhea.

- It is caused by several bacterial, viral and parasitic organisms.
- It spreads through contaminated water due to poor sanitation, personal and domestic hygiene. Sources include human feces surrounding a rural water source, or from municipal sewage, septic tanks and toilets in urban centers.

- The feces of domestic animals also contain microorganisms that can cause diarrhea through water.
- Food is a major cause of diarrhea when prepared in unhygienic conditions.
- Fish and seafood from polluted water can cause severe diarrhea.
- Polluted water can also contaminate vegetables during irrigation.

Interventions: Key measures to reduce the number of cases of diarrhea include:

- access to safe drinking water,
- improved sanitation,
- good personal and food hygiene, and
- health education about how these infections spread.

Key measures to treat diarrhea include:

- giving more fluids than usual (oral rehydration) with salt and sugar, to prevent dehydration,
- continued feeding, and
- consulting a health worker if there are signs of dehydration or other problems.

In rural India, during the last decade, public education through posters and other types of communication strategies has decreased infant mortality due to diarrhea in several states. Posters depicting a child with diarrhea being given a salt and sugar solution to reduce death from dehydration has gone a long way in reducing both—a serious condition requiring hospitalisation and intravenous fluids, as well as mortality.

7.3.5 Risks Due to Chemicals in Food

Food contaminated by chemicals is an important public health concern. This contamination may occur through environmental pollution of the air, water and soil. Toxic metals, PCBs and dioxins, or the intentional use of various chemicals, such as pesticides, animal drugs and other agrochemicals have serious consequences on human health. Food additives and contaminants used during food manufacture and processing also adversely affect human health.

Diseases spread by food: Some food-borne diseases, though well recognised, have recently become more common. For example, outbreaks of salmonellosis which have been reported for decades, has increased within the last 25 years. In the Western hemisphere and in Europe, Salmonella serotype Enteritidis (SE) has become a predominant strain. Investigations of SE outbreaks indicate that its emergence is largely related to the consumption of poultry or eggs.

While cholera has devastated much of Asia and Africa for years, its reintroduction for the first time in almost a century on the South American continent in 1991 is an example of a well-recognised infectious disease re-emerging in a region after decades. While cholera is often water-borne, many foods also transmit the infection. In Latin America, ice and raw or under-processed seafood are important causes for cholera transmission.

Infection with a specific type of *Escherichia coli* (*E. coli*) was first described in 1982. Subsequently, it has emerged rapidly as a major cause of bloody diarrhea and acute renal failure. The infection is sometimes fatal, particularly in children. Outbreaks of infection, generally associated with beef, have been reported in Australia, Canada, Japan, the US, various European countries and in southern Africa. Outbreaks have also implicated alfalfa sprouts, unpasteurised fruit juice, lettuce, game meat (meat of wild animals) and cheese curd.

In 1996, an outbreak of *E. coli* in Japan affected over 6,300 school children and resulted in 2 deaths.

Listeria monocytogenes (Lm): The role of food in the transmission of this condition has been recognised recently. In pregnant women, infections with Lm cause abortion and stillbirth. In infants and persons with a poor immune system, it may lead to septicemia (blood poisoning) and meningitis. The disease is most often associated with consumption of foods like soft cheeses and processed meat products that are kept refrigerated for a long time, because Lm can grow at low temperatures. Outbreaks of listeriosis have been reported from many countries, including Australia, Switzerland, France and the US. Two recent outbreaks of Listeria monocytogenes in France in 2000 and in the USA in 1999 were caused by contaminated pork tongue and hot dogs, respectively.

Food-borne trematodes (worms) are increasing in Southeast Asia and Latin America. This is related to a combination of intensive aquaculture production in unsanitary conditions, and the consumption of raw or underprocessed freshwater fish and fishery products. Food-borne trematodes can cause acute liver disease, and may lead to liver cancer. It is estimated that 40 million people are affected worldwide.

7.3.6 Cancer and the Environment

Cancer is caused by the uncontrolled growth and spread of abnormal cells that may affect almost any tissue of the body. Lung, colon, rectal and stomach cancer are among the five most common cancers in the world for both men and women. Among men, lung and stomach cancer are the most common cancers worldwide. For women, the most common cancers are breast and cervical cancer. In India, oral and pharyngeal cancers form the most common type of cancers, which are related to tobacco chewing.

More than 10 million people are diagnosed with cancer in the world every year. It is estimated that there will be 15 million new cases every year by 2020. Cancer causes 6 million deaths every year or 12% of the deaths worldwide.

The causes of several cancers are known. Thus, the prevention of at least one-third of all cancers is possible. Cancer is preventable by stopping smoking, providing healthy food and avoiding exposure to cancer-causing agents (carcinogens). Early detection and effective treatment is possible for a further one-third of cases. Most of the common cancers are curable by a combination of surgery, chemotherapy (drugs) or radiotherapy (X-ray technology). The chance of the cure increases if the cancer is detected at an early stage.

Cancer control is based on the prevention and control of cancer by:

- promoting and strengthening comprehensive national cancer-control programs,
- building international networks and partnerships for cancer control,
- promoting organised, evidence-based interventions for the early detection of cervical and breast cancer,
- developing guidelines on disease and programme management,
- advocating a rational approach to effective treatments for potentially curable tumours, and
- supporting low-cost approaches to respond to global needs for pain relief and palliative care.

Prevention of Cancer

Tobacco smoking is the single-largest preventable cause of cancer in the world. It causes 80% to 90% of all lung cancer deaths. Another 30% of all cancer deaths, especially in developing countries, include deaths from cancer of the oral cavity, larynx, esophagus and stomach, which are related to tobacco chewing. Preventive measures include bans on tobacco advertising and sponsorship, increased tax on tobacco products and educational programs to reduce tobacco consumption.

Dietary modification is an important approach to cancer control. Overweight individuals and obesity are known to be associated with cancer of the esophagus, colon, rectum, breast, uterus and kidney. Fruits and vegetables may have a protective effect against many cancers. The excessive consumption of red and preserved meat may be associated with an increased risk of colorectal cancer. Infectious agents are linked with 22% of cancer deaths in developing countries and 6% in industrialised countries.

More on cancers

- Viral hepatitis B and C cause cancer of the liver. Human papilloma virus infection causes cancer of the cervix.
- The bacterium *Helicobacter pylori* (*H. pylori*) increases the risk of stomach cancer.
- In some countries, the parasitic infection schistosomiasis increases the risk of bladder cancer.
- Liver fluke increases the risk of cancer of the bile ducts. Preventive measures include vaccination and prevention of infection.
- Excessive solar UV radiation increases the risk of all types of cancer of the skin. Avoiding prolonged exposure to the sun, as well as the use of sunscreens and protective clothing, are effective preventive measures.
- Asbestos is known to cause lung cancer.
- Aniline dyes have been linked to bladder cancer.
- Benzene can lead to leukemia (blood cancer).
- The prevention of certain occupational and environmental exposure to several chemicals such as benzene, asbestos and aniline dyes is an important element in preventing cancer.

7.4 HUMAN RIGHTS

Several environmental issues are closely linked to human rights. These include the equitable distribution of environmental resources, the utilisation of resources and Intellectual Property Rights (IPRs), conflicts between people and wildlife especially around PAs, resettlement issues around development projects such as dams and mines, and access to health to prevent environment-related diseases. All of these aspects have been discussed in Chapter 6.

7.5 VALUE EDUCATION

Value education in the context of our environment is expected to bring about a new sustainable way of life. Education, both through formal and non-formal processes, must thus address understanding environmental, natural and cultural values, social justice, human heritage, equitable use of resources, managing common property resources and the causes of ecological degradation.

Essentially, environmental values cannot be taught. They are inculcated through a complex process of appreciating our environmental assets and experiencing the problems caused due to the destruction of our environment. The problems that are created by technology and economic growth are a result of our improper thinking on what development means. Since we still put a high value only on economic growth, we have no concern for aspects such as sustainability or equitable use of resources. This mindset must change before concepts like sustainable development can be acted upon.

What are values?

Values deal with ones own principles and standards from which we judge what kind of behaviour is right or wrong.

Values in environment education must bring in several new concepts. Why and how can we use less resources and energy? Why do we need to keep our surroundings clean? Why should we use less fertilisers and pesticides in farms? Why is it important for us to save water and keep our water sources clean? Or segregate our garbage into degradable and non-degradable types before disposal? All these issues are linked to the quality of human life and go beyond simple economic growth. They deal with a love and respect for nature. These are the values that will bring about a better humanity, one in which we can live healthy, productive and happy lives in harmony with nature.

7.5.1 Environmental Values

Every human being has a great variety of feelings for different aspects of his or her surroundings. The Western, modern approach values the resources of nature for their utilitarian importance alone. However, true environmental values go beyond valuing a river for its water, a forest for its timber and NTFPs, or the sea for its fish. Environmental values are inherent in feelings that bring about sensitivity for preserving nature as a whole. This is a more spiritual, Eastern, traditional value. There are several writings and sayings in Indian thought that support the concept of the oneness of all creation, of respecting and valuing all the different components of nature. Our environmental values must also translate into pro-conservation actions in all our day-to-day activities. Most of our actions have adverse environmental impacts unless we consciously avoid them. The sentiment that attempts to reverse these trends is enshrined in our environmental values.

Values lead to a process of decision making which leads to action. For value education in relation to the environment, this process is learned through an understanding and appreciation of nature's oneness and the importance of its conservation.

Humans have an inborn desire to explore nature and to unravel its mysteries. However, modern society and educational processes have invariably suppressed these innate sentiments. Once exposed to the wonders of the wilderness, people tend to bond closely with nature. They begin to appreciate its complexity and fragility and this awakens a new desire to want to protect our natural heritage. This feeling for nature is a part of our constitution, which strongly emphasises this value.

Concepts of what constitutes 'right' and 'wrong' behaviour change with time; values are not constant. It was once considered 'sport' to shoot animals. It was considered a royal, brave and desirable activity to kill a tiger. In today's context, with wildlife reduced to a tiny fraction of what there was in the past, it is now looked down upon as a crime against biodiversity conservation. Thus, the value system has been altered with time and circumstances. Similarly, with the large tracts of forest that existed in the past, cutting a few trees was not a significant criminal act. Today, this constitutes a major concern. With the small human numbers in the past, throwing away a little household degradable garbage could not have been considered wrong. But with enormous numbers of people throwing away large quantities of non-degradable waste, it is indeed extremely damaging to the environment and our value system must prevent all this through a strong environmental value education system.

Appreciating the negative effects of our actions on the environment must become a part of our day-to-day thinking. Our current value system extols economic and technical progress as being what we need in our developing country. While we do need economic development, our value system must change to one that makes people everywhere support a sustainable form of development so that we do not have to bear the cost of environmental degradation.

Environmental problems created by development are due neither to the need for economic development, nor to the technology that produces pollution, but rather to a lack of awareness of the consequences of unlimited and unrestrained anti-environmental behaviour. Looked at in this way, it deals with concepts of what is appropriate behavior in relation to our surroundings and to other species on earth. How we live our lives in fact shapes our environment. This is what environmental values are about.

Each action by an individual must be linked to its environmental consequences in his/her mind, so that a value is created that strengthens pro-environmental behaviour and prevents anti-environmental actions. This cannot happen unless new educational processes are created that provide a meaning to what is taught at school and college level. Every child asks questions like 'What does this mean?' They want an explanation for things happening around them that can help them make decisions and through this process develop values. It is this innate curiosity that leads to a personalised set of values in later life. Providing appropriate 'meanings' for such questions related to our own environment develops a set of values that most people in society begin to accept as a norm. Thus, pro-environmental actions begin to move from the domain of individuals to that of a community.

At the community level, this occurs only when a critical number of people become environmentally conscious so that they constitute a pro-environment lobbying force that makes governments and other people accept good environmental behaviour as an important part of development.

What professions require making value judgments that greatly influence our environment? Evidently nearly every profession can and does influence our environment, but some do so more than others. Policy-makers, administrators, landuse planners, media, architects, medical personnel, health-care workers, agriculturalists, agricultural experts, irrigation planners, mining experts, foresters, forest planners, industrialists and most importantly, teachers at the school and college levels, are all closely related to pro-environmental outcomes.

Environmental values are linked to varied environmental concerns. While we value resources that we use as food, water and other products, there are also environmental services that we must appreciate. These include nature's mechanisms in cleaning up air by removal of carbon dioxide and addition of oxygen by plant life, recycling water through the water cycle of nature and maintaining climate regimes.

Let's take a pledge

- I will work towards the protection of our environment and the preservation of our wild species.
- I will work towards this with other like-minded individuals.
- I will consciously avoid committing acts that damage our environment and will publicly assert my dislikes for acts against the environment.
- I will not permit others to cause harm to the wilderness and our wild species without protest.
- I will use resources carefully by reducing, reusing and recycling whatever I use, such as water, paper, plastic, metal and glass articles.
- I will not carelessly throw away items that are made of our precious natural resources.
- I will use energy carefully and switch off electrical appliances when not in use.
- I will not waste energy by using a fuel-based vehicle when I can walk or cycle.
- I will visit our wondrous wild places with clean air, water, soil and all their plants and animals, and become a party to their conservation.
- I will not permit any individual or government action to spoil our environment or damage wilderness without protest.
- I will always care for Mother Earth.
- I will try not to damage her, knowingly or unknowingly.

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However, there are other aesthetic, ethical values that are equally important aspects of our environment that we do not appreciate consciously. While every species is important in the web of life, there are some which man has come to admire for their beauty alone. The tiger's magnificence, the whale and elephant's giant size, the intelligence of our cousins the primates, the graceful flight of a flock of cranes, are all parts of nature that we cannot help but admire. The lush splendor of an evergreen forest, the great power of the ocean's waves, and the tranquility of the Himalayan mountains are things that each of us values even if we do not experience it ourselves. We value its being there on earth for us. This is called its 'existence value'.

We must also look at our environment beyond the wild sphere. There is incredible beauty in some human-modified landscapes, the coloured patterns of farmland or the green hues of a tea or coffee plantation in the hills.

Urban gardens and open spaces are also valuable and must be of prime concern to urban planners. These green spaces act as not only the 'lungs' of a city, but also provide much-needed psychological support. The mental peace and relaxation provided by such areas needs to be valued, although it is difficult to put a price tag on these values. Nevertheless, these centres of peace and tranquility give urban dwellers an opportunity to balance their highly modified environments with the splash of green of a garden space. Dr Ernest Wilson believed, as many do today, that these green spaces are vital to our mental and physical well-being; he coined the term *biophilia* to describe this.

Environmental values must also stress on the importance of preserving ancient structures. The characteristic architecture, sculpture, artworks and crafts of ancient cultures are invaluable environmental assets. They tell us where we have come from, where we are now, and perhaps (if we are willing to learn from them) where we should go. Architectural heritage goes beyond preserving old buildings, to conserving whole traditional landscapes in rural areas and streetscapes in urban settings. Unless we learn to value these landscapes, they will disappear and our heritage will be irrevocably lost.

As environmentally conscious individuals we need to develop a set of values that are linked with a better and more sustainable way of life for all people. There are several positive as well as negative aspects of behaviour that are linked to our environment. The positive feelings that support environment include a value for nature, cultures, heritage and equity. We also need to become more sensitive to aspects that have a negative impact on the environment. These include our attitude towards the degradation of the environment, loss of species, pollution, poverty, corruption in environmental management, the rights of future generations and animal rights.

Toshiv Raj

7.5.2 Valuing Nature

The most fundamental environmental sentiment is to value nature herself. The oneness of our lives with the rest of nature and a feeling that we are only a miniscule part of nature's complex web of life becomes apparent, when we begin to appreciate the wonders of nature's diversity. We must appreciate that we belong to a global community that includes another 1.8 million known living forms. We know for sure that the earth's life-forms are unique. We have a great responsibility to protect life in all its glorious forms and must therefore respect the wilderness with all its living creatures, where human beings have not created changes that have led to perturbing natural habitats. We need to develop a sense of value that leads us to protect what is left of the wilderness. On the one hand, we need to protect natural ecosystems, while on the other we must protect the rights of local people.

Apart from valuing the diversity of life itself, we must also learn to value and respect diverse human cultures. Many of the tribal cultures of our country are vanishing because those with more dominant and economically advanced ways of life do not respect their lifestyles that are, in fact, closer to nature and frequently more sustainable. We believe that our modern technology-based lifestyles are the sole way for society to progress. Yet, this is only a single dimension of life that is based on economic growth.

While currently the environmental movement focuses on issues that are concerned with the management of the natural environment for the 'benefit' of man, 'Deep Ecology' promotes an approach that is expected to bring about a more appropriate ecological balance on earth and is akin to a spiritual approach to nature.

CASE STUDY 3

Deep ecology

In the 1970s, a new thinking on environmental concerns began to emerge, protecting nature and the wilderness for its own sake, which is now referred to as 'Deep Ecology'. It was fostered by the thinking of Arne Naess, a Norwegian professor of Philosophy and a great believer in Gandhian thinking and Buddhism. It recognises the intrinsic value of all living beings and looks upon mankind as a small segment of a great living community of life-forms. It teaches that the well-being and flourishing of human and non-human life on earth have value in themselves and that these values are independent of the usefulness of the non-human world for human purposes.

Another new approach is that of *Gaia*, the hypothesis that the earth is itself like one giant form of throbbing life consisting of all the unquantifiable numbers of individuals of its millions of known and unknown species.

7.5.3 Valuing Cultures

Every culture has a right to exist. Tribal people are frequently most closely linked with nature and we have no right to foist on them our own modern way of life. The dilemma is how to provide them with modern health care and education that gives them an opportunity to achieve a better economic status without disrupting their culture and way of life. This will happen only if we value their culture and respect their way of life.

7.5.4 Social Justice

As the gulf widens between the haves and the have-nots, it is the duty of the former to protect the rights of the latter. If this is not respected, the poor will eventually rebel, anarchy and terrorism will spread and the people who are impoverished will eventually form a desperate seething revolution to better their own lot. The developing world will face a crisis earlier than the developed countries, unless we protect the rights of poor people.

CASE STUDY 4

Darfur murders

An example of consequences of social injustice can be found in the genocidal murders in the Darfur region of Africa. Darfur is in the part of Africa that includes southern Sudan to the east of Lake Chad where such murders have become commonplace. Niger, which is just west of Lake Chad has regionwide drought leading to famine conditions, affecting millions. While there are many complex political causes of the famine and genocide, one of the major contributing factors is the disappearance Lake Chad—the sixth largest lake in the world! This lake has shrunk to one-twentieth of its original size due to declining rainfall and mismanagement (over-extraction) of the water resources. It has affected millions of people who depended on these waters for crop irrigation, fishing, livestock and drinking water.

Modern civilisation is a bland, homogenous culture, based until recently on a belief that modern science holds the answer to everything. We are now beginning to appreciate that many ancient and even present-day sequestrated cultures have a wisdom and knowledge of their own environments that is based on a deep sense of respect for nature. Tribal cultures have, over many generations, used indigenous medicines which are proving to be effective against diseases. They have produced unique art forms, such as painting, sculpture and crafts, which are beautiful and can enrich living experiences for everyone. They have their own poetry, songs, dance and drama—all art forms that are unfortunately being rapidly lost as we introduce a different set of modern values to them through television and other mass media. The world will be culturally impoverished if we lose this traditional knowledge. They will soon lose the beauty within their homes that is based on the things they make from nature. The art of the potter will be lost forever to the indestructible plastic pot. The bamboo basket-weaver who makes a thing of beauty that is so user-friendly and aesthetically appealing, will give place to yet another plastic box. Much that is beautiful and hand-crafted will disappear if we do not value these diverse aspects of human cultures.

7.5.5 Human Heritage

The earth itself is a heritage left to us by our ancestors, not only for our own use but also for the generations to come. There is much that is beautiful on our earth—the undisturbed wilderness, a traditional rural landscape, the architecture of a traditional village or town and the value of a historical monument or place of worship. These are all part of our human heritage.

Heritage preservation is now a growing environmental concern, because we have undervalued much of this heritage during the last several decades and it is vanishing at an astonishing pace. While we admire and value the Ajanta and Ellora Caves, the temples of the 10th to 15th centuries that led to different and diverse styles of architecture and sculpture, the Moghul styles that led to structures such as the Taj Mahal, or the unique environmentally-friendly colonial buildings, we have done little to actively preserve them. As environmentally conscious individuals, we need to lobby for the protection of the wilderness and our glorious architectural heritage.

7.5.6 Equitable Use of Resources

An unfair distribution of wealth and resources, based on a world that is essentially only for th rich, will bring about a disaster of unprecedented proportions. The equitable use of resource is now seen as an essential aspect of human well-being and must become a shared point of vie among all socially and environmentally conscious individuals. In spite of the great numb of people in the more populous developing countries, the smaller number of people in t developed countries use more resources and energy than those in the developing world. Th is equally true of the small number of rich people in poor countries whose per capita use energy and resources, and the generation of waste based on the one-time use of disposab products, leads to great pressures on the environment. As we begin to appreciate that we ne more sustainable lifestyles, we also begin to realise that this cannot be brought about witho a more equitable use of resources.

7.5.7 Common Property Resources

Our environment has a major component that does not belong to any individual. There several commonly owned resources that all of us recycles, the air that we all breathe, the forests and grasslands which maintain our climate and soil, are all common property resources. When the government took over the control of community forests in British times, the local people who until then had controlled their use through a set of norms that were based on equitable use, began to overexploit the resources in which they now had no personal stake. Bringing back such traditional management systems is extremely difficult. However, in the recent past managing local forests through village-level FPCs has shown that if people know that they can benefit from the forests, they will begin to protect them. This essentially means sharing the power to control forests between the Forest Department and the local people.

7.5.8 Ecological Degradation

In many situations, valuable ecological assets are turned into serious environmental problems. This is because we, as a society, do not strongly resist forces that bring about ecological degradation. These consist of sectors of society that use a get-rich-quick approach to development. While ecological degradation has frequently been blamed on the needs of fuelwood and fodder of growing numbers of rural people, the rich, urbanised, industrial sector is responsible for greater ecological damage. The changes in landuse from natural ecosystems to more intensive utilisation (such as turning forests into monoculture forestry plantations, tea and coffee estates) or marginal lands into intensive agricultural patterns (such as sugarcane fields) or changes into urban or industrial land carry an ecological price. For example, wetlands provide usable resources and a variety of services not easily valued in economic terms; when destroyed to provide additional farmland, in many cases they produce lower returns. A natural forest provides valuable NTFPs, whose economic returns far outweigh that provided by felling the forest for timber. These values must form a part of a new conservation ethic. We cannot permit unsustainable development to run onwards at a pace in which our lives will be overtaken by a development strategy that must eventually fail as earth's resources are consumed and ecosystems rendered irreparable.

7.6 HIV/AIDS

The Human Immuno-deficiency Virus (HIV) causes Acquired Immunodeficiency Syndrome (AIDS) through contact with the tissue fluids of infected individuals, particularly through sexual contact. As it reduces an individual's resistance to disease, it causes infected individuals to suffer from a large number of environment-related diseases and reduces the ability of infected individuals to go about their normal lives. It saps their strength, leads to skin lesions (Karposi's sarcoma) and they become increasingly vulnerable to any air or water borne pollutants, until they eventually die.

In sub-Saharan Africa, where the infection has become highly prevalent, it is leading to great suffering and worsening poverty. These patients become unable to work and their usual sources of income generation are lost. An increasing proportion of the poor are affected. Incomes lost due to the stigma of HIV/AIDS are usually met by the sufferers by overexploiting their resource base, as they are not in any position to think of the long-term future. In Africa, this has led to degradation of the ecosystem and an increase in pressures due to other impacts such as the overuse of medicinal plants and poaching of wildlife. In South Africa, for example people have a mistaken belief that turtle eggs can cure HIV/AIDS, thus leading to the eggs being over-harvested. When males die of the disease, agricultural work has to be taken over by already overburdened women and children, affecting land management and productivity. Providing balanced diets and nutritional support for these poverty-stricken patients can be partially addressed by better natural resource management like afforestation, access to clean water and wholesome food.

HIV/AIDS has a serious impact on the socioeconomic fabric of society. In 2007, India had an estimated 2.5 million infected individuals. There is a great need to organise AIDS education on prevention and management of the disease. This needs to be done through the formal educational sector and by using non-formal methods. Education is also important to reduce the stigma and discrimination against these patients. In India and sub-Saharan Africa, women who are not socially empowered are at a great disadvantage as they are powerless to demand safe sex from their partners. Women also have an added burden of caring for HIV-infected husbands. This produces enormous economic stresses on their family. HIV in India is rapidly moving from being a primarily urban disease to rural communities.

Blood transfusion from an infected person can also lead to HIV/AIDS in the recipient, as well as drug abuse by sharing needles with an infected person. However, the most important measure to prevent AIDS is the proper use of condoms that form a barrier to the spread of the virus during intercourse.

7.7 WOMAN AND CHILD WELFARE

There are several environmental factors that are closely linked to the welfare of women and children. Each year, close to eleven million children worldwide have been estimated to have died from the effects of disease and inadequate nutrition. Most of these deaths are in the developing world. In some countries, more than one in five children die before they are 5 years old. Seven out of ten childhood deaths in developing countries can be attributed to five main causes, or a combination of them. These are: pneumonia, diarrhea, measles, malaria and malnutrition. Around the world, three out of every four children suffer from at least one of these conditions.

Respiratory conditions: Most respiratory diseases are caused by or are worsened by polluted air. Living in crowded, ill-ventilated homes with smoky, open fires can trigger respiratory conditions, especially in children.

CASE STUDY 5

The *chulha* issue

According to a study conducted in 2005 by the World Health Organisation, it was estimated that 1.6 billion early deaths occur annually from cooking stove pollution. Between 400,000 to 550,000 children less than five years and women die each year in India due to indoor smoke. *Chulha* smoke is the third-highest cause of disease and death, after dirty water and lack of sanitation. Hence, by providing access to clean water, sanitation, food and well-ventilated homes, over half the diseases and premature deaths could be avoided in India.

Pneumonia: Acute respiratory infections (ARI), most frequently pneumonia, is a major cause of death in children under five years, killing over two million children annually (WHO, 2009). Up to 40% of children seen in health centers suffer from respiratory conditions and many deaths attributed to other causes are, in fact, hidden ARI deaths. Children may die very quickly from the infection and thus need treatment urgently. Most patients of pneumonia can be treated with oral antibiotics. Correct management could save over 1 million lives every year globally.

Measles: Measles is a rash that appears with fever and body ache in children and is caused by a virus. It infects over 200,000 children and kills over 150,000 children under the age of five (WHO, 2009). Its prevention includes wider immunisation coverage, rapid referral of serious cases, prompt recognition of conditions that occur in association with measles and improved nutrition, including breastfeeding, and vitamin A supplements. Measles can be prevented by a vaccine. Young children with measles often develop other diseases like acute respiratory infections, diarrhea and malnutrition that are all linked to poor environmental conditions in their surroundings. Children who survive an attack of measles are more vulnerable to other dangerous infections for several months. Effective prevention and treatment could save at least 150,000 lives per year.

Poverty–environment–malnutrition: There is a close association between poverty, a degraded environment and malnutrition. This is further aggravated by a lack of awareness on how children become malnourished.

Malnutrition: Although malnutrition is rarely listed as the direct cause of death, it contributes to about half of all childhood deaths. Lack of access to food, poor feeding practices (inadequate breastfeeding, providing the wrong type of food or insufficient food) and infection, or a combination of the two, are the major causes of mortality.

Infection, particularly frequent or persistent diarrhea, pneumonia, measles and malaria, undermines nutritional status. Children between 6 months and 2 years of age are at increased risk of malnutrition, when there is a transition between breastfeeding and sharing fully in the family diet. Changing family habits and the kinds of food offered to children is an important measure. Talking to mothers individually about home care and their child's feeding, with relatively simple changes to better feeding practices, such as helping them to eat rather than leaving them to fend for themselves, can ensure that a child gets enough to eat.

There are strong connections between the status of the environment and the welfare of women and children in India. Women, especially in lower-income groups, both in the rural and urban sectors, work longer hours than men. Their work pattern differs and is more prone to health hazards. The daily collection of water, fuelwood and fodder is an arduous task for rural women. In urban areas, where lower economic group women live in crowded smoke-filled shanties in unhygienic slums, they spend long hours indoors, leading to respiratory diseases. In urban centers, a number of women eke out a living by garbage picking. They separate plastics, metal and other recyclable material from the waste. During this process, they can get several infections.

Women and girls tend to compromise and get inadequate nutrition. They are often the last to eat, as their role in traditional society is to cook the family meal and feed their husband and sons first. In terms of access to educational facilities, the girl child is given less importance as compared to boys in India. Thus, they are unable to compete with men in later life. This social–environmental divide is a major concern that needs to be corrected throughout the country.

7.8 ROLE OF INFORMATION TECHNOLOGY IN ENVIRONMENT AND HUMAN HEALTH

The understanding of environmental concerns and issues related to human health has exploded during the last few years due to the sudden growth of information technology. With the help of computer technologies, we can do several tasks extremely rapidly, accurately and spread the information through the world's networks of millions of computer systems.

A few examples of the use of computer technology that aid environmental studies include software such as using Geographical Information Systems (GIS). GIS is a tool to map landuse patterns and document change by studying digitised toposheets and/or satellite imagery. Once this is done, an expert can ask a variety of questions which the software can answer by producing maps which help in landuse planning. The internet, with its thousands of websites, has made it very simple to get appropriate environmental information for any study or environmental management planning. This not only assists scientists and students but is a powerful tool to help increase public awareness about environmental issues.

Table 7.2 Symptoms for common conditions

Complaint/symptom	Possible cause or associated condition
Cough and/or fast breathing	Pneumonia Severe anemia *P. falciparum* malaria
Lethargy or unconsciousness	Cerebral malaria Meningitis Severe dehydration Very severe pneumonia
Measles rash	Pneumonia Diarrhea Ear infection
'Very sick' young infant	Pneumonia Meningitis Sepsis

CASE STUDY 6

Karnataka's GIS scheme, *Bhoomi*, has revolutionised the way farmers access their land records. Farmers can now get a copy of the records of rights, tenancy and crops from a computerised information kiosk without harassment and bribes. Karnataka has computerised 20 million records of land ownership of 6.7 million farmers in the state.

Specialised software can analyse data for epidemiological studies, population dynamics and a variety of key environmental concerns. The relationship between the environment and health has been established due to the growing utilisation of computer technology. This looks at infection rates, morbidity or mortality and the etiology (causative factors) of a disease. As our knowledge expands, computers will become increasingly efficient.

Summary

- With the increasing world population, natural resources are under increasing pressure, threatening public health and development. All the environmental challenges of water shortages, loss of biodiversity, air and water pollution and climate change, greatly impact human health. Thus, environment and human health are closely interlinked.
- A better health status of society will bring out a better way of life only it is coupled with stabilising population growth.

Questions

1. Why is an effective Family Welfare Program crucial for India's progress? What are some of the major reforms required to achieve an effective FWP for India?
2. An improvement in health is central to sound environmental management. Discuss at least three strategies that will help strengthen this link.
3. Discuss with an example, how climate change affects human health.
4. Discuss and explain the wilderness–rural–urban link. You can use a diagram to aid your discussion.

Unit 8

Field Work

Let's understand

- The procedure to visit a local area to document environmental assets—river, forest, grassland, hill or mountain
- The procedure to visit a local polluted site
- How to study common plants, insects and birds
- How to study a simple ecosystem

8.1 VISIT TO A LOCAL AREA TO DOCUMENT ENVIRONMENTAL ASSETS: RIVER/FOREST/GRASSLANDS/HILL/MOUNTAIN

Background

Documenting the nature of an ecosystem gives us a deeper appreciation of its value to mankind. Each ecosystem has something different to offer. It may contain natural resources that local people depend on; provide important ecological functions; have tourist or recreational potential; or simply have a strong aesthetic appeal that is difficult to quantify in economic terms. In fact, it can have multiple benefits for mankind at the global, national and local levels. An ecosystem is not only used in various ways by people belonging to different cultures and socio-economic groups, but has a different significance for different individuals, depending on their way of life. A tribal from a wilderness setting, an agriculturalist from farmlands, a pastoralist from grasslands or a fisherman looks at his or her environment very differently from an urban resident who is mainly focussed on the management of the quality of air and water, and the disposal of garbage. In many cultures, men and women have different views and relationships with nature. In rural India, for example, it is mostly women who collect resources and see the degradation of their ecosystem as a serious threat to the existence of their family. They are thus more involved and will fight against processes that lead to the loss of their resource base.

Tribal people who live by hunting and gathering have a deep understanding of nature and what it provides for them to survive. Farmers know how to utilise their land and water resources, and also appreciate what droughts and floods can do to their lives. A shepherd or livestock

The Need for Sustainable Development and Biodiversity Conservation for a New Emerging India

The great strides in economic development that India has made in the last two decades is remarkable. While this has resulted in improving incomes in several sectors of society, it has also had side effects leading to the loss of a real 'quality of life' of a large proportion of people. A large trigger for this deterioration has been the fact that the natural resources on which economic development has been essentially based (both directly and indirectly), has been seriously misused in the last few decades. In the rapidly expanding urban and potential megacities of India, the quality of life, as judged by different stakeholders, has shown that their access to resources such as water, air, land, housing and amenities such as health care, availability of green space, recreation, security and peace has actually decreased! The time spent in congested traffic has led to a loss of their personal productivity. Increasing pollution is seen as a cause of ill health and preventive health care is sorely missing. Most people in urban India now feel that the 'happiness' that economic development should have produced with their better salaries is only related to availability of more consumer goods and products. However, their overall quality of life has deteriorated!

In the rural sector, the loss of several traditional value systems that supported a homogeneous and equitable use of resources, in many parts of India, has in fact widened the gap between the rich and the poor. This has resulted from changes in lifestyles induced by current development strategies such as irrigated farming, overuse of fertilisers and pesticides. The loss of equitable use of resources has resulted from inadequately designed development strategies which are not suited to the reality of the rural world. While all traditional practices are not necessarily required in the present context of development, some of them are of great value in maintaining ethical, moral and other concerns related to societal equity and a feeling of togetherness. The wilderness dwellers, especially the tribals, who subsist on products from forests, grasslands, wetlands, mountains and semiarid ecosystems have lost, (and are continuing to lose) the very foundations of the ecological setting of their traditional homeland. This is a great threat to their lives and livelihoods which strongly negates their 'happiness'. This has led to social unrest and strife at the regional level. These wilderness areas where they have lived for generations are the last bastions of biologically valuable hotspots and unique cultural diversity of our country. The development of dams and other mega projects displaces them from their own environment and destroys their wellbeing. Development strategies for these eco-dependant societies must thus focus on education and health care with respect for their livelihoods, traditions, folklore and cultural inheritance.

While urbanisation and industrialisation have enhanced economic development, it has led to degrading of forests, grasslands, mountains, rivers and wetlands. This has created increasing disparities in wealth. It has also impacted biological diversity and led to severe climate changes.

These two major concerns are the most important challenges that the world must face. An overarching strategy that can be provided for all these different sectors for a more sustainable economic, social and environmental management, can fast-track these complex developmental issues towards a sustainable future. This requires a change in formal educational processes. The creation of better equitable access to health and education are crucial to sustainable development. The protection and preservation of all natural resources, (especially wilderness resources) and biodiversity is most important for a sustainable future. Management of resources that includes air, water, biodiversity, food, nutrition and mitigating effects of climate change, are elements of sustainability that must be addressed.

The answer seems to be placing scientific management for conservation of resources and developing alternate energy sources consideration as a central theme of all development sectors without necessarily slowing economic growth. This strategy must include mitigative measures such as eco-restoration of degraded land, reforestation using local plant species and biodiversity preservation, at the core of a new thinking on development. Industrial growth, for example, must be planned so that the total environmental impact of all the industries in a region is within the carrying capacity of its natural resources and energy production. Irrigation to spur agricultural growth cannot succeed in the long term if wilderness and its biodiversity are eliminated from the region. Urban sprawl without sustainability will undoubtedly lead to ill health from environment-related diseases—social strife and proneness to disaster.

This new cross cutting interdisciplinary approach to development must not be seen as a measure that will curtail economic growth, but as an innovative engine for development that will continue to steer the world sustainably over the next several generations.

The fruits of better environmental management, biotechnology based on supporting nature's wealth of bioresources, and education and awareness of the need for sustainable growth, are integrally linked with the economic societal and environmental concerns through strategies based on good governance. Enhancing public awareness and infusion of these concepts into educational processes at all levels is a key to its success as it requires lifestyle alterations for people everywhere.

The judicious management of our ecological goods and services for sustainable use today, with a new focus on the future, must make itself overt in all sectorial policy documents. A better environment is one that is more conducive to all sectors of society, protecting a wider range of living beings (both flora and fauna), that from a silent web of life is an integral part of human wellbeing. This can be implemented both within our National Parks and Sanctuaries as well as by preserving the genetic diversity of our indigenous crops and live stock.

GLOBAL LEVEL

The development over the last two centuries has been linked entirely to the needs of economic growth of developed nations. This has been at the cost of the poorest nations whose resources have been over-exploited. In the developing world, the rapid explosion of population has created poverty and ill health. Unsustainable economic growth has thus led to threats to our environment at global, national and local levels.

Since it is obvious that economic development has not led to the wellbeing of people across the globe, a new thinking on what constitutes 'development' has become necessary. The challenges for a development strategy that the earth can sustain in the long term are manyfold and often highly locale-specific. However, these local or regional threats to the environment eventually affect the whole world. Many of these challenges that have arisen from our current pattern of unsustainable development must be thus addressed at global, national, state, local and even individual levels. The management of resources is essentially different in the urban, rural and wilderness context. Much can be achieved if all of us adopt measures that lead to more sustainable lifestyles. This includes a respect for nature and all her resources. Management of water, air, land and biodiversity are all closely linked to sustainable development.

URBAN SUSTAINABILITY

In the urban and megacity environments, sustainable cities can be created if we adopt measures to conserve energy, use alternate energy sources, develop better public transport, use non-polluting vehicles that reduce emissions, create and implement better water conservation measures in our daily lives, and ensure better sewage and solid waste management at the city and the individual household level. Reducing our use of consumer goods that add to waste is a key aspect to urban management.

Thus, sustainability related issues need a new pattern of urban governance so that water, housing, health, education, entertainment and urban green space for recreation in natural surroundings are used equitably.

RURAL SUSTAINABILITY

In the rural sector, water for irrigation, better landuse and green cover management, preserving our great diversity of crops and maintaining our indigenous livestock breeds are the main concerns. Preservation of indigenous knowledge of nutrition and traditional health care remedies can bring about a healthier life. The impact of overuse of fertilisers and pesticides is a health hazard for farmers as well as the consumers of these polluted agricultural products. Rural nutritional support and preventive health still remains a major concern, even twelve years after the 'Health for all by 2000' was to be achieved.

WILDERNESS SUSTAINABILITY

For the people who depend directly on goods and services from forests, grasslands, wetlands, coastal and hill ecosystems for all their needs, the rapid changes triggered by economic growth has seriously altered their environment. Land use changes have made them resource-poor and even homeless.

Thus, the change required to move from unsustainable to sustainable development must begin at the grassroots level. This includes involving a variety of public and private institutions as well as by creating more sustainable personal lifestyles. Much of this can be dealt with through enlightened local governance. However, this needs relevant educational inputs and local capacity building. If each individual uses resources , the world will become a better place to live in.

Sustainable development can be defined as development that meets the needs of the current generation without compromising the change of future generation to meet their own needs.

SUSTAINABILITY, HOW EDUCATION AND AWARENESS CAN MAKE IT HAPPEN...

There has been a large gap between the understanding the need for sustainability and its implementation. Bridging the gap requires a platform for spreading the need for sustainable development through education and public awareness. The UN has declared the current decade as being focussed on sustainable development. India's Twelfth Five Year Development Plan also expects the country to move towards long term sustainability in every sector. With half of the UN decade of 'Education for Sustainable Development' completed, India is nowhere near an implementable strategy for furthering sustainable development through school and college education. It took India several decades to implement aspects related to Environment Education into curricula in spite of a ruling by the Hon. Supreme Court to the Ministry of Human Resource and Development. One can thus expect a similar lag phase for Education for Sustainable Development (ESD) unless this is placed on a fast track. A beginning for ESD must come from appreciating the differences between EE and ESD. The bases for EE are the appreciation of the natural world and how its degradation affects all people everywhere. ESD goes beyond the scope of EE into an understanding of the links between the three basic pillars of sustainability which include economic, social and environmental concerns. The interrelationships and checks and balances between these three support systems define whether 'development' is unsustainable or sustainable. ESD is highly site- and community-specific. There is no simplistic one way strategy to reorient unsustainable economic development towards a sustainable course. The needs of global sustainability encompasses all people everywhere. However, there is a need to create local and national strategies that feed into long term global goals. Sustainable development is concerned with everyone's lifestyles in developed, emerging and the developing world. This again demands specific approaches to SD.

In the developed countries SD must deal with reducing existing impacts of their previous unsustainable development patterns on natural resources. Their dependence on resources of poor countries has led to global effects on human health, peace and harmony. For the developed countries, sustainability is primarily linked to reducing consumerism and waste generated by affluent societies. There is also a need to reduce emissions from fossil fuels released by vehicles and industry. Bringing down the use of fossil based energy and reducing energy requirements at all levels is a serious and urgent issue.

In the *developing world*, sustainable development is concerned with using a strategy towards economic growth that will not hinder the lives of future generations. However, seriously restricting the use of natural resources and the use of energy would be decidedly unfair and bring about further inequalities. The impact of poverty and population growth in developing countries is closely linked to the level of sustainability. Containing population growth and poverty alleviation combined with a lack of basic education, is a major concern in the developing economically disadvantaged societies.

In the emerging countries such as India and China, the issues related to SD are those seen in both the developed and the developing countries. This further adds to the complexity of bringing about a common understanding of sustainability that would be relevant for all sections of Indian society. The need to provide an action-related education and awareness strategy for all the different stakeholders that affect sustainability at individual and community levels is a major challenge in India. Appreciating the ill effects of unsustainable development designed for rapid economic growth is the first step towards the understanding of sustainability.

Since the majority of development issues deal with the utilisation of resources and energy, or the consequences of their misuse and overuse, it is essential that people everywhere appreciate the new challenges that characterise the over use of nature's resources in relation to the needs of future generations. A matrix of parameters linked to the levels of sustainability based on the three pillars of development (economic social and environmental) can be used to conceptualise design and implement learning strategies that can be used for an action oriented teaching 'Education of Sustainable Development'.

Sustainable lifestyle changes that every individual can make contribute to the overall 'quality of life' of us all. This requires an action oriented component to education that must be appreciated by each and every one of us.

Milestones Towards a Sustainable World

International

1972: UN Conference on the Human Environment, Stockholm
1987: Brundtland Report
1992: UN Conference on Environment and Development, Rio de Janeiro
1997: Rio+5 Conference, New York
2002: UN World Summit on Sustainable Development, Johannesburg
2012: Conference on Sustainable Development «Rio+20»

Indian

1997: Ninth Five-Year Plan
2002: The Biological Diversity Act
2002: Tenth Five-Year Plan
2004: The Biological Diversity Rules
2006: National Environment Policy
2007: Eleventh Five-Year Plan
2012: Twelfth Five-Year Plan

Matrix: The ESD Learning Matrix (A)—Urban Context

Quality of life concerns	Economic issues		Social issues		Environmental issues	
	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable
Water	(a) High cost of potable water is not paid for. (b) Poor sewage management leads to waste of water and higher costs. (c) Supply to some sectors by tankers is very expensive. (d) Polluted water leads to high health service costs.	(a) Potable water from all taps 24 × 7, if waste is reduced. (b) Adequate sewage management by reducing waste of water. (c) Recycling waste water reduces cost.	(a) Access to adequate water supply denied to the disadvantaged sector leads to societal disruption.	(a) All sectors get adequate potable water and this reduces social tensions.	(a) High level of water pollution (rivers, lakes). (b) High levels of waste of clean water. (c) River pollution leads to costly health hazards downstream.	(a) Clean up river and lake water. (b) Water available and potable at all times in adequate amounts through better management. (c) Prevention of wastage. (d) Rain water harvesting.
Housing	(a) High cost of land and housing leads to slum development.	(a) Growth that has affordable places to live, of good quality without the development of slums.	(a) Formation of slums is an indicator of unequal development among different sectors of society.	(a) Homes of good quality available for all sectors of society leads to a harmonious city development.	(a) Unplanned growth that leads to environmental degradation, and health impacts.	(a) Growth in consonance with availability of land and resources through sound planning, with recreational facilities, education and green space.

Health	(a) Poor access to preventive health care leads to higher costs for curative medicine.	(a) Preventive health measures reduce costs. (b) All forms of curative health available at affordable costs.	(a) Unequal access to health care. (b) Lack of adequate preventive health for economically deprived.	(a) Equal access for all sectors of society. (b) Low levels of morbidity and mortality from preventable diseases.	(a) Threat of environment related disease—both endemic and epidemic. (b) High incidence of respiratory diseases due to air pollution.	(a) Control of vector borne diseases (b) Control over water borne and water related diseases. (c) Reduce air pollution for a healthy city.
Energy	(a) High cost due to wasted energy. (b) Rising costs but still subsidised due to large amount of wasted supply.	(a) Use energy saving devices and alternate energy sources—solar, wind, bioenergy to reduce cost. (b) Reducing energy waste individually has a large positive cumulative outcome.	(a) Inequitable distribution of energy needs. (b) Overuse by rich.	(a) Education and awareness reduces energy use, especially in transport sector. (b) Should be available for the deprived sectors at lower cost.	(a) Fossil fuels will be used up completely, making the use of alternatives with low impacts on environment essential. (b) Pollutes the environment by fossil fuel burning.	(a) Reducing energy use and minimising waste will help mitigate climate change. Clean up of air by use of alternate energy—solar wind power, bioenergy.

Quality of life, other concerns	Economic issues		Social issues		Environmental issues	
	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable
Nutrition	(a) Unaffordable price of good nutritious food. (b) Use of fertilisers and pesticides.	(a) Affordable good uncontaminated food, reduces cost on health care, and leads to better work output. (b) Use of organic farming products.	(a) Poor nutritional status of deprived section affects the whole population.	(a) All sections get adequate nutritious food, leads to better work output.	(a) Food is of poor quality due to contamination. (b) Flies are out of control due to solid waste generation.	(a) Food is of nutritious quality and incidence of chemical contamination related diseases is lowered. (b) Vectors such as flies are kept under control by better waste management.
Security	(a) Inadequate police force leads to a need for costly private security. (b) Post disaster management has high costs.	(a) Adequate policing to prevent crime, better social justice. (b) Disaster prevention is cost effective.	(a) Poor and religious groups feel insecure. Women feel Insecure. (b) Disasters affect the poor.	(a) All parts of society feel secure—rich, poor all ethnic and religious groups are secure. (b) All people have reduced risk.	(a) Unsafe environment by day and night. Feeling of fear, due to insecure areas of the city. (b) Post disaster effects can last for years.	(a) Feel safe at all times. Evergreen feels safe in all parts of the city/village. (b) Risk minimisation prevents disasters.
Job availability and satisfaction	(a) Pays are inadequate and there are jobless people—both skilled and unskilled.	(a) Jobs are available and pays are adequate for all types of skills.	(a) Training for jobs is inadequate. (b) Use of child labour remains a socially unacceptable practice.	(a) Training for jobs is available for all types of people in all walks of life. (b) Support for all childrens' education.	(a) Unsafe labour which is accident and/or disease prone.	(a) Adequate protection against environment related and industry related accidents and/or diseases.
Recreation	(a) Lack of recreational space due to inadequate planning and/or implementation due to high cost of land.	(a) Adequate recreational activities, garden space, affordable sports, exposure to visual and performing arts at low cost.	(a) Available only for the upper economic groups.	(a) Available for all sectors of society.	(a) Lack of adequate green space. (b) Low levels of urban biodiversity, affects psychological wellbeing.	(a) Adequate amount and quality of green space, presence of urban biodiversity is of great relevance to reduce urban stress.

Quality of life indicators	Economic issues		Social issues		Environmental issues	
	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable
Air/water pollution	(a) Cost of pollution cleanup is very high.	(a) Pollution is prevented at source reduces cost of health care, and prevents morbidity and mortality.	(a) Polluter is not penalised.	(a) Polluter pays principle put into place.	(a) Dirty river. (b) Lack of green cover. (c) Unbreathable air. (d) Undrinkable tap water.	(a) Clean river with fish, birds as indicators. (b) Clean breathing air 24 × 7.
Solid waste management	(a) Lack of 3Rs—Reuse, Reduce, Recycle; leads to serious economic loss.	(a) Good solid waste management at individual and family level can reduce solid waste and make it manageable.	(a) Waste production is by the affluent sector.	(a) Waste is recycled by rag pickers whose health is at stake.	(a) Unmanageable quantum of urban waste has high health implications.	(a) Better management through recycling, developing bio-fertilisers from household waste.
Transport	(a) Use of four or two wheelers which are afforded only by rich sector. (b) Waste of productive time due to traffic jams.	(a) Adequate rapid transit system for all sectors. (b) Better implementation of traffic rules prevents traffic jams and reduces fuel consumption.	(a) High levels of road rage. (b) Only rich can afford their own transport which is safe and adequate only for themselves.	(a) Implementation of traffic rules prevents accidents. (b) Under-privileged also have access to good means of public transportation.	(a) Traffic jams. (b) High numbers of road traffic accidents. (c) Use of highly air polluting transport is a serious health concern.	(a) Lower density of traffic across all parts of the city through public transport systems. (b) Use of cycles. (c) Space for walking is made available.
Green space and urban biodiversity	(a) High cost of maintenance of lawns in gardens.	(a) Design of gardens with low cost and high carbon sequestration.	(a) Only available at high cost and in private households.	(a) Free or low cost and usable by all through public gardens.	(a) Lack of adequate planning for urban biodiversity conservation.	(a) Visually a green city. (b) Tree covered avenues reduce heat islands. (c) Biodiversity preserved as a provider of well being. (d) Use of Biodiversity Act.
Heritage	(a) Unsupported economic inputs into heritage conservation.	(a) Conserving heritage is given adequate financial support from city funds, identifies living space.	(a) Lack of societal support for conserving heritage.	(a) Shared costs for maintaining heritage with involvement of citizens leads to pride in one's own city.	(a) Degradation of heritage structures. Heritage structures covered with advertisements and graffiti leading to visual loss of identity.	(a) Environmentally sound maintenance of all heritage structures and natural features provides a great living experience.

Quality of life indicators	Economic issues		Social issues		Environmental issues	
	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable
Education and awareness	(a) Clean schools only in private institutes (b) Green schools are expensive.	(a) Hygiene must be financially supported in Municipal Corporation schools. (b) Green schools for lower economic sector.	(a) Inadequate attention to health education (b) Green schools restricted to the rich.	(a) Adequate health education for all schools (b) Whole school approach for green concepts.	(a) Environment education and Education for Sustainable Development not provided.	(a) Intracurricular EE and ESD provided through teacher capacity building for green eco schools.
Population pressure	(a) Economic growth creates in-migration but lacks financial resources to support growth of population in urban areas.	(a) Economic growth sees to it that migratory population is adequately supported.	(a) Unequal distribution of land and resources for growing population. (b) Lack of family welfare.	(a) Good management planning to reduce population growth. (b) Use of family welfare programs.	(a) Deteriorating environments due to population growth in slum areas.	(a) Environmental protection measures to counter effects of population growth through good planning and governance.
Governance	(a) Financial management and technological inputs into 'good' governance is lacking.	(a) 'Good' governance is supported adequately by people's initiative which reduces costs.	(a) Unequal governance guided by money power. (b) Land grab and speculation. (c) Corruption.	(a) Attention to all sectors of society. (b) Health and education for all is a priority.	(a) Lack of planning and implementation of environmental concerns.	(a) Encouraging public awareness and environment education for demanding better governance. (b) Use of RTI (Right to information act).
Consumerism	(a) High costs of living. (b) Large waste component. (c) Short term gains in business terms.	(a) Learning sustainability reduces long-term costs.	(a) Available only for higher economic groups. (b) Consumer products are used in large amounts and not for sustaining needs.	(a) Poor must have adequate access to goods and feel satisfied.	(a) Produces insurmountable waste of goods, and overuse of plastic, energy. (b) Waste management is insurmountable.	(a) Use what one needs not for greed.

The ESD Learning Matrix: (B)—Rural Context

Quality of life indicators	Economic issues		Social issues		Environmental issues	
	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable
Water	(a) High demand of water due to rapid urbanisation, industrialisation, population explosion, deprives rural sector. (b) Overuse/misuse of water in irrigation for cash crops. (c) Unsustainable use in agriculture (irrigation). (d) Issues related to pricing for water in different sectors. (e) Degradation and drainage of wetlands.	(a) Demand should be met by following the 3R principle. (b) Economic long term benefits of reduced and sustainable use of water. (c) Appropriate irrigation facilities. (d) Crops with low water requirements should be encouraged. (e) Economically affluent sections and industry should pay a higher price. (f) Conservation of wetlands for their multiple ecological services is cost effective.	(a) Inequitable, large distribution of water to urban and industrial sectors. (b) Local water conflicts (river water in India, drought prone areas). (c) Price of water is not rationalised. (d) Conflicts over water use in irrigation sector. (e) Loss of fish resources for traditional fishermen.	(a) Equitable distribution of water for all sectors including irrigation. (b) The conflicts should be resolved by debate and equity. (c) Ideally potable water should be free for all. The price normally includes the high cost related to the distribution system and energy use which must be reduced. (d) Better equitable management in rural sector. (e) Livelihood support for local fishermen.	(a) Poor sanitation facilities, especially in developing rural regions. (b) Severe water pollution, urban, industrial, fertilisers, pesticides. (c) No utilisation of rain water harvesting in low rainfall areas. (d) Unplanned water management degrades ecosystems. (e) Loss of wetlands endangers aquatic flora and fauna.	(a) High level of low cost sanitation should be implemented for rural sector. (b) Proper pollution prevention facilities at all levels. (c) Rain water harvesting should be made mandatory in all regions. (d) Sustainably planned water management, supports ecosystem services. (e) Conservation of aquatic flora, fauna and ecosystem.

Quality of life indicators	Economic issues		Social issues		Environmental issues	
	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable
Land	(a) Unsustainable change in land use pattern for economic gain for a few speculators. (b) Rapid transition to industrialisation and urbanisation.	(a) Land use pattern should be such that economic, social and environmental balance is maintained. (b) Planned landuse strategy for all sectors.	(a) No land for traditional tribal forest dwellers, thus they are deprived of their traditional rights over the forest. (b) Establishment of poorly planned Special Economic Zones (SEZs).	(a) Concepts and programmes like Community Reserves, JFM, and ecodevelopment plans should be encouraged. (b) Create stringent laws for SEZs.	(a) Loss of precious biodiversity, increase in deforestation, increase in wastelands. (b) Poorly legislated Industrial growth has long term negative impacts on environment.	(a) Strong Protected Area Network, and Ecorestoration should be facilitated. (b) Planned environmentally sensitive growth in rural and wilderness sectors with proper zoning.
Biodiversity	(a) Destruction of indigenous species due to unplanned land use which have long term values for biotechnology, food security, and futuristic use.	(a) Conservation of the indigenous species for their option value (for example, for future use in medicine or industries).	(a) Exploitation of traditional knowledge based natural resources by outside people for various uses (for example, indigenous plants for the pharmaceutical industry).	(a) Understanding the concept of Intellectual Property Rights (IPR) by traditional forest communities and benefit sharing.	(a) Destruction of wilderness and exploitation of species; poaching of plants and animals leads to endangering species, and permanent extinction.	(a) Need for a better Protected Area Management. Developing corridors. (b) Wildlife laws at ground level are implemented to conserve biodiversity.
Forestry	(a) Overexploitation of forest products for timber value and have long term value and industrial products and unnecessary packaging.	(a) Extraction of forest products should be allowed only at the carrying capacity of the forest.	(a) Local people or traditional forest dwellers are deprived of their rights over the forest.	(a) Traditions that safeguard the forest should be encouraged (for example, the sacred groves of the forest communities).	(a) All forest functions like watershed protection, atmospheric regulation, erosion control, local and market use of the forest products are at stake due to deforestation, desertification and other destructive activities.	(a) Better Protected Area Management (National Parks and Sanctuaries) through involvement of local communities for protection of the forest.

Quality of life indicators	Economic issues		Social issues		Environmental issues	
	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable
Agriculture/ pastoralism	(a) Intensive agriculture, dependence on cash crops, through monoculture, creates risk.	(a) Use of traditional agricultural systems that permits a wide range of produce to be grown and marketed throughout the year.	(a) Farmers receive economic incentives to grow cash crops for national and international market, rather than to supply local needs. (b) Local food shortage, rural unemployment (as cash crops are usually mechanised). Landlessness and increased vulnerability to droughts and floods.	(a) Local supply of food is important for wellbeing. (b) Traditional agriculture should be encouraged as it acts as an insurance against the failure of a cash crop for small farmers.	(a) Reduction in soil fertility due to overuse, monoculture, high drought and flood conditions, desertification due to overgrazing. (b) Loss of cultivars of ancient origin.	(a) Mix of crops or crop rotation practiced to maintain soil fertility. (b) Proper selection of the crops depending upon the soil structure and well managed use of grazing areas. (c) Conservation of traditional knowledge of local germ plasm for future use.
Fisheries	(a) Overharvesting of fish using highly mechanised boats and use of trawling by commercial groups because of high demand and rapid economic returns.	(a) Proper harvesting of fish for commercial purposes. Overharvesting should be avoided at all costs for long term sustainability of fisheries.	(a) Traditional fisher folk are negatively affected.	(a) Commercial fishing should be sustainable considering the livelihood needs of traditional fisher folk.	(a) Diversity of fish is reducing. Many are threatened by extinction.	(a) Proper balance between commercial harvesting and protection of fish diversity.

Quality of life indicators	Economic issues		Social issues		Environmental issues	
	Unsustainable	Sustainable	Unsustainable	Sustainable	Unsustainable	Sustainable
Mining	(a) Current overexploitation of minerals for their very high economic value. (b) Minerals not recycled adequately leads to high cost. (c) Mining leads to long term soil and biodiversity loss, and long term economic loss.	(a) Overexploitation and high cost should be prevented by reducing consumerist life styles.	(a) Mining poses several long term occupational hazards to the miners. (b) Safety of the miners is a big issue. (c) Mining areas deprive local people of their forest resources. (d) Mining depletes biodiversity.	(a) Proper health protection measures for miners. (b) Proper safety measures for the workers should be implemented. (c) Mined out areas must be restored.	(a) Over extraction of the mining products from the lithosphere has a variety of side effects such as deforestation. (b) Fossil fuel is non-renewable. (c) Depletion of forest land, increasing waste land, pollution of air and water. (d) Loss of natural ecosystems such as forests leading to local biodiversity extinction.	(a) Differences between exploitation and overexploitation should be understood by the mining companies. (b) Shifting dependence from non-renewable to renewable energy sources. (c) Public awareness, and government actions are essential to stem the damage caused to the environment. (d) Ecorestorative mining techniques prevents loss of biodiversity in mined out land.

Multiple Choice Questions

CHAPTER 1: THE MULTIDISCIPLINARY NATURE OF ENVIRONMENTAL STUDIES

1. Environmental studies involves
    - (a) Biology and geology
    - (b) Physics and chemistry
    - (c) Anthropology and economics
    - [✓ (d)] All of the above
2. Impacts of industrial development are
    - (a) Natural resource depletion
    - (b) Deforestation which in turn leads to floods
    - (c) Decrease in non renewable (petroleum) resources
    - [✓ (d)] All of the above
3. The important aspects of sustainable development are:
    - (a) High levels of consumption expenditure and low levels of saving
    - (b) Intra and inter-generational inequity
    - (c) Intra and inter-generational equity
    - (d) None of the above
4. World Environment Day falls on
    - [✓ (a)] 5 June
    - (b) 28 February
    - (c) 4 October
    - (d) 22 April
5. M S Swaminathan is
    - (a) Is an ornithologist
    - (b) Is an ecologist
    - [✓ (c)] Is an agricultural scientist
    - (d) Is a journalist

CHAPTER 2: NATURAL RESOURCES

1. During photosynthesis, green plants take in
    - (a) Oxygen
    - [✓ (b)] Carbon dioxide
    - (c) Sulphur
    - (d) Nitrogen

2. Which of the following is an example of a non-renewable resource?
   [✓ (a) Coal and minerals]
   (b) Soil
   (c) Water
   (d) Wind

3. Which of the following is an example of a non-renewable energy resource?
   (a) Solar
   (b) Methane
   (c) Hydroelectric
   [✓ (d) Coal]

4. Nuclear energy is now being generated in the world using
   (a) Nuclear fission
   (b) Nuclear fusion
   [✓ (c) Both (a) and (b)]
   (d) Neither (a) nor (b)

5. Build up of toxic material at the top of the food chain is called
   (a) Detoxification
   (b) Toxicology
   [✓ (c) Biomagnification]
   (d) None of the above

6. Desertification is caused by
   (a) Mining
   (b) Deforestation
   (c) Overgrazing
   [✓ (d) All of the above]

7. The ideal location for installation of wind mills is
   [✓ (a) Coastal regions]
   (b) Evergreen forests
   (c) Deserts
   (d) Mountainous regions

8. Dicholorodiphenyltrichloroethane is otherwise known as
   [✓ (a) DDT]
   (b) Aldrin
   (c) Gammexane
   (d) None of the above

9. Important forest products are
   (a) Resins
   (b) Nuts
   (c) Timber
   [✓ (d) All of the above]

10. What type of energy is derived from heated groundwater?
   (a) Solar energy
   (b) Geothermal energy
   [✓ (c) Hydroelectric energy]
   (d) Nuclear

CHAPTER 3: ECOSYSTEMS

1. Which one of the following is **not** an indicator of the quality of an ecosystem?
   (a) Population of species or the percentage of species loss
   (b) [✓ Economic value of the ecosystem]
   (c) Species diversity of the ecosystem
   (d) State of change or state of 'naturalness' of the ecosystem

2. The organisms which feed on the waste products are called
   (a) Herbivores
   (b) Carnivores
   (c) [✓ Detrivores]
   (d) Chemovores

3. Stages in the water cycle:
   (a) Two
   (b) Three
   (c) Four
   (d) Five

4. The tropical grasslands of Africa are known as
   (a) Pampas
   (b) Prairies
   (c) Steppes
   (d) Savannahs

5. The scientific term for algal bloom is called
   (a) [✓ Eutrophic]
   (b) Macrotrophic
   (c) Chemotrophic
   (d) None of the above

6. The shola grasslands are found in
   (a) The Himalayas
   (b) The Vindhyas
   (c) The Western Ghats
   (d) The Eastern Ghats

7. The Little Rann of Kutch is the only home of the
   (a) Great Indian Bustard
   (b) Indian Wild Ass
   (c) Blackbuck
   (d) [✓ Flamingo]

8. Among the ecosystems mentioned below, where can one find maximum biodiversity?
   (a) Mangroves
   (b) Desert
   (c) [✓ Coral reefs]
   (d) Grasslands

9. The structural aspects of the ecosystem includes
   (a) Producers
   (b) Consumers

(c) Decomposers
[✓ (d) All of the above]

10. Guano deposits are rich in
    (a) Nitrogen
    [✓ (b) Phosphorus]
    (c) Sulphur
    (d) Potassium

Phosp

CHAPTER 4: BIODIVERSITY

1. The diversity that enables life on earth to adapt and sustain environmental changes is called
    (a) Functional diversity
    (b) Genetic diversity
    (c) Species diversity
    (d) Ecosystem diversity

2. The number of different species an ecosystem contains is its
    (a) Speciation
    (b) Species evenness
    (c) Habitat
    [✓ (d) Species richness]

3. The number of hotspots of biodiversity that exist in India is
    (a) 5
    (b) 9
    (c) 14
    (d) 18

4. Which of the following is not a major characteristic feature of biodiversity hot spots?
    (a) Large number of species
    (b) Abundance of endemic species
    (c) Large number of exotic species
    [✓ (d) Destruction of habitat]

5. A species restricted to a specific area is known as
    [✓ (a) Endemic]
    (b) Exogenic
    (c) Exclusive
    (d) None of the above

6. Illegal killing of endangered species is known as
    (a) Rustling
    (b) Poaching
    (c) Thieving
    (d) Plundering

7. In India, pelicans breed in
    (a) Kokkare Bellur
    (b) Koonthankulam
    (c) Nelapattu
    (d) All of the above

8. The only true antelope found in India is
   - (a) Chinkara
   - (b) Chausingha
   - (c) Blackbuck
   - (d) Nilgai

CHAPTER 5: POLLUTION

1. Dobson units are used to measure
   - [✓ (a) Thickness of the ozone layer]
   - (b) Loudness of sound
   - (c) Amount of CFCs in the atmosphere
   - (d) None of the above

2. The presence of air pollutants during rain causes
   - (a) Low acidity
   - (b) Neutral conditions
   - [✓ (c) High acidity]
   - (d) None of the above

3. The toxic susbstance in the Bhopal gas tragedy was
   - (a) NO_2
   - (b) SO_2
   - (c) DDT
   - [✓ (d) MIC]

4. Technological controls for particulates in industry include:
   - (a) Scrubbers
   - (b) Precipitators
   - (c) Filters
   - [✓ (d) All of the above]

5. Minamata disease was caused by eating fish which had high levels of
   - [✓ (a) Arsenic]
   - (b) Mercury
   - (c) Cadmium
   - (d) All of the above

6. Sulphur dioxide contributes to the following problems except
   - (a) Damage of buildings
   - (b) Acid rain
   - (c) Death of vegetation
   - (d) Loss of biodiversity in aquatic ecosystems
   - (e) Photochemical smog

7. Bioaccumulation of DDT in birds of prey results in
   - (a) Premature breaking of eggs
   - (b) Thin shells of eggs
   - [✓ (c) Both (a) and (b)]
   - (d) Neither (a) nor (b)

8. Secondary sewage treatment can be best described as being a
   - (a) Chemical process
   - (b) Biological process
   - (c) Mechanical process
   - (d) Geological process

9. Soil erosion can be checked by
   - (a) Contour trenches
   - (b) Bunds
   - (c) Gabions
   - (d) All of the above

10. Waste is classified as hazardous if it is
    - [✓ (a) Toxic]
    - (b) Reactive
    - (c) Corrosive
    - (d) None of the above
    - (e) All of the above

11. The effects of a cyclone can be mitigated by
    - (a) Developing shelter belts
    - (b) Training and education
    - (c) Developing communication infrastructure
    - [✓ (d) All of the above]

CHAPTER 6: SOCIAL ISSUES AND THE ENVIRONMENT

1. Calcium in the bones gets replaced by an element which is liberated during a nuclear explosion. That element is
   - (a) Magnesium
   - (b) Barium
   - (c) Strontium
   - (d) Radium

2. Sheep and cattle release the following greenhouse gas
   - (a) CO_2
   - (b) Methane
   - (c) Nitrous oxide
   - (d) All of the above

3. The idea of sustainable development was defined in
   - (a) 1977
   - (b) 1987
   - (c) 1997
   - (d) 2007

4. The advantage of implementing rainwater harvesting is
   - (a) It recharges ground water levels
   - (b) It reduces run-off

(c) It avoids flooding
(d) All of the above

5. Of the traditional water harvesting systems employed in Rajasthan, a stone embankment built on a hill-slope to help create a level field for cultivation is called
   (a) Hembar
   (b) Chak
   (c) Naada
   (d) Medhbandi

6. The Chipko movement was started by
   (a) Ananda Devi
   c [✓ (b)] Amrita Devi
   (c) Gandhiji
   (d) Sunderlal Bahuguna

7. Ozone layer depletion is caused by
   c [✓ (a)] CFCs
   (b) NO_2
   (c) Methane
   (d) CO

8. Which of the following is not a major contributor to the greenhouse effect?
   (a) Carbon dioxide
   (b) Carbon monoxide
   [✓ (c)] Chlorofluorocarbons
   (d) Methane gas
   (e) Nitrous oxide

9. Which of the following is not a likely result of global warming?
   (a) Rising sea levels
   [✓ (b)] Increased agricultural productivity worldwide
   (c) Increased storm frequency and intensity
   (d) Worsening health diseases and their impacts

10. Maximum ozone depletion has been observed over
    [✓ (a)] The North Pole
    (b) The South Pole
    (c) The equator
    (d) None of the above

11. The people of Tehri implemented an innovative scheme involving
    (a) Rainwater harvesting
    (b) Terrace farming
    (c) Micro-watershed development
    (d) All of the above

12. Which of the following represents an idea associated with environmental sustainability?
    (a) The capacity of the environment to absorb pollutants/toxins is unlimited
    (b) The human population can continue to grow
    (c) We can use fossil fuels as if they are in unlimited supply

(d) The earth's resources are not present in infinite supply
(e) Dilution is the solution to pollution

13. The Wildlife Protection Act was passed in
    (a) 1986
    (b) 1974
    (c) 1972
    (d) 1980

CHAPTER 7: HUMAN POPULATION AND THE ENVIRONMENT

1. Cancer causing agents are known as
    (a) Mutagens
    (b) Teratogens
    (c) Neurogens
    (d) Carcinogens

2. A measure of population growth is
    (a) Growth rate
    (b) Doubling time
    (c) Both (a) and (b)
    (d) Neither (a) nor (b)

3. Sustainable development was first clearly defined by the
    (a) Bruntland Commission
    (b) Rio Conference
    (c) United Nations
    (d) World Bank

4. Temporary method of birth control is
    (a) Condoms
    (b) Intrauterine devices
    (c) Oral contraceptive pills
    (d) All of the above

5. ENSO occurs across the Pacific ocean roughly once in
    (a) 2 years
    (b) 3 years
    (c) 4 years
    (d) 5 years

6. Malaria is spread through the bite of the female mosquito
    (a) Anopheles
    (b) Aedes
    (c) Culex
    (d) All of the above

7. The chemical that can lead to leukemia is
    (a) Asbestos
    (b) Aniline
    (c) Phenol
    (d) Benzene

8. Deep ecology fostered by the thinking of Arne Naess
   (a) Recognises the intrinsic value of all living things
   (b) Recognises the importance of the oceans
   (c) Recognises the intrinsic value of thick forests
   (d) None of the above

9. HIV/AIDS can spread from an infected person through
   (a) Saliva
   (b) Sweat
   (c) Clothes
   [✓ (d) Syringe]

Websites

Websites and/or emails of Environmental Organisations

Bharati Vidyapeeth Institute of Environment Education and Research (BVIEER)
Email: bvieer@vsnl.com

Bombay Natural History Society (BNHS)
Web: www.bhns.org, Email: bnhs@bom4.vsnl.net.in

Botanical Survey of India (BSI)
Web: www.nic.in, Email: bsi@gems.vsnl.net.in

Center for Environment Education (CEE)
Web: www.education.vsnl.com/cee/index.html, Email: cee@ceeindia.org

Center for Science and Environment (CSE)
Web: www.cseindia.org, Email: cse@cseindia.org

CPR Environment Education Center
Web: www.cpreec.org, Email: cpreec@vsnl.net

Crane Foundation
Web: www.cranes.org

Defenders of Wildlife
Web: www.defenders.org

Earth Sanctuaries Ltd (ESL)
Web: www.esl.com.au

Indian Board of Wildlife (Project Tiger)
Web: www.envfor.nic.in

International Rhino Foundation (IRF)
Web: www.rhinos-irf.org/rhinos-

International Wolf Centre
Web: www.wolf.org

Kalpavriksh, Pune
Web: www.kalpavriksh.tripod.com, Email: kvriksh@vsnl.com

Madras Crocodile Bank Trust (MCBT)
Email: mcbtindia@vsnl.net

National Audubon Society
Web: www.audubon.org

National Wildlife Federation (NWF)
Web: www.nwf.org

Nature Conservancy
Web: www.nature.org

Nature Conservation Foundation (NCF)
Web: www.ncf-india.org

Northern India Bird Network
Web: www.delhibird.org

Ocean Conservancy
Web: www.oceanconservancy.org

People for Animals
Web: www.peopleforanimals.org

Salim Ali Center for Ornithology and Natural History (SACON)
Web: www.saconindia.com, Email: sacon@vsnl.net

Sanctuary Asia
Web: www.sanctuaryasia.com

Tiger Trust
Web: www.fontayne.com/tigertrust

Traffic
Web: www.traffic.org

Uttarakhand Seva Nidhi (UKSN)
Email: pandey@nde.vsnl.net.in

WHT
Web: www.wht.org

Wilderness Society, The
Web: www.wilderness.org.au

Wildlife Conservation Society (WCS)
Web: www.wcs.org

Wildlife Institute of India (WII)
Web: www.wii.gov.in, Email: wii@wii.gov.in

Wildlife Tust of India (WTI)
Web: www.wildlifetrustofindia.org

World Wide Fund for Nature-India (WWF-India)
Web: www.wwfindia.org, Email: communications@wwfindia.net

Zoological Survey of India (ZSI)
Email: dirzsi@wb.nic.in

'Environmental studies' has become an undisputed requirement in the syllabi of all undergraduate courses. The first edition of this textbook was the outcome of the efforts of the Expert Committee constituted by the UGC in response to the directive given by the Supreme Court of India, on the necessity for a basic course on the environment. The Second Edition has incorporated the feedback from the students and faculty to make it more user-friendly.

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- Questions are provided at the end of each chapter to test comprehension.

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